

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-261 047

Composting at Johnson City: Final Report on
Joint USEPA-TVA Composting Project with
Operational Data, 1967 to 1971. Vol I-II

Environmental Protection Agency, Washington, D C

Nov 75

EPA/530/SW-31r.2
NOVEMBER 1975
349093

261 047

composting at johnson city

final report on Joint USEPA-TVA project

Environmental Protection Agency
Library
401 M Street, S.W., Room 2404
Washington, D.C. 20460
PM-213

a current report
on solid waste management

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA/530/SW-31r.2	2.	3. Recipient's Accession No.
	4. Title and Subtitle Composting at Johnson City -- Final report on joint USEPA-TVA project with Operational Data, 1967 to 1971, Volumes I and II		5. Report Date Nov 1975
7. Author(s) Vol I - Gordon E. Stone; Carlton C. Wiles; Vol II - C. C. Wiles	8. Performing Organization Rept. No.		6.
9. Performing Organization Name and Address Same as box 12	10. Project/Task/Work Unit No.		11. Contract/Grant No.
	12. Sponsoring Organization Name and Address U.S. Environmental Protection Agency Office of Solid Waste Management Programs		13. Type of Report & Period Covered
15. Supplementary Notes A current report on solid waste management			14.
16. Abstracts This report combines the interim report of investigations conducted and operational experiences from the Joint USEPA-TVA Compost Project during the period June 1967 to September 1969, as Volume I, and the operational data and experiences obtained during the period October 1969 through June 1971, as volume II, into one report.			
17. Key Words and Document Analysis. 17a. Descriptors			
17b. Identifiers/Open-Ended Terms			
17c. COSATI Field/Group			
18. Availability Statement		19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 360
		20. Security Class (This Page) UNCLASSIFIED	22. Price 10.50

COMPOSTING AT JOHNSON CITY
Final Report on Joint USEPA-TVA Composting Project
/ with Operational Data, 1967 to 1971

Volumes I and II

Volume I (formerly interim, open-file report SW-31r.1.of)
covers the period from June 1967 to September 1969
and was prepared by GORDON E. STONE and CARLTON C. WILES

Volume II covers the period from October 1969 to June 1971
and was prepared by CARLTON C. WILES

Both volumes (SW-31r.2) were prepared
under the direction of CLARENCE A. CLEMONS

U.S. ENVIRONMENTAL PROTECTION AGENCY

1975

PREFACE

The Joint USEPA-TVA Composting Project* began operation in June 1967. The purposes of the project were related to the need to investigate the technical and economical feasibility of windrow composting as a method of managing municipal refuse. The feasibility of composting sewage sludge with the ground refuse was also to be investigated. Equipment was to be evaluated and costs of various parts of the process were to be determined. Potential health problems associated with composting municipal refuse with sewage sludge were considered extremely important, therefore, the survival during composting of pathogenic organisms in the refuse or sewage sludge was to be determined. In addition, the benefits available from using the compost in various applications were to be evaluated. An assessment was to be made of the economical benefits from using compost for agricultural, horticultural, or soil amendment purposes. A determination was also to be made as to the maximum amount of refuse compost that the soil might accept without adverse effects.

Results of investigations conducted and operational experiences from the project during the period June 1967 to September 1969 were reported. The current report combines that interim report, as Volume I, and the operational data and experiences obtained during the period October 1969 through June 1971, as Volume II, into one report.

*Formerly "Joint USPHS-TVA Composting Project".

The major studies concerned with the technical aspects of wind-row composting were conducted during the first period, and Volume I presents the results of these investigations. Although Volume II serves to update these results, it is primarily concerned with presenting a status report of the research and demonstration projects being conducted to investigate the utilization of the compost produced at the Johnson City composting plant. These studies were only in preliminary stages at the time Volume I was first published.

Research concerned with soil and plant responses to organic and other supplements often requires years before meaningful results can be achieved. Thus the compost utilization research and demonstration projects are being continued. Results of the continued research will be reported in appropriate scientific and other journals of interest.

ACKNOWLEDGEMENT

The completion of this report was made possible by the cooperation of many individuals, two Federal agencies, and a municipality.

The Tennessee Valley Authority (TVA) must be credited with the foresight to develop a composting system in a part of the country where the soil would benefit from the compost produced by a successful composting facility. The design and operation of the facility was the sole responsibility of TVA. O. M. Derryberry, F. E. Gartrell, O. W. Kochtitzky, W. K. Seaman, Jack Taylor, Carroll Duggan, and Virgil Rader were just a few of the TVA people participating. David Burkhalter and James Mosier, as city managers, were responsible for implementing the needed cooperation from the Johnson City municipality.

John S. Wiley, well known for his pilot research on composting, served as Research Director until his retirement on July 1, 1968. Gordon E. Stone became Project Engineer in July 1967, and served in that capacity until he was appointed the solid waste management representative for the Environmental Protection Agency's Region II. Carlton Wiles was then appointed Project Engineer and served in that capacity until the project was completed in June 1971. Fred J. Stutzenberger, staff microbiologist; Donald J. Dunsmore, staff sanitary engineer; and Richard D. Lossin, staff chemist, performed the majority of the tests and studies reported. Some of the assay work was performed by personnel of the Research Services Laboratory in Cincinnati. W. L. Gaby and his

staff at East Tennessee State University worked closely with project personnel in determining that compost was safe, under study conditions, for agricultural use. Mirdza L. Peterson, research microbiologist, served as the contract officer for a portion of these studies. Marie T. Presnell, serving as administrative assistant, has been a key person in assuring the continued smooth operation of the project. The Cincinnati-based managers included Harry Stierli, Charles G. Gunnerson, and C. A. Clemons. Andrew W. Breidenbach provided the general direction for the entire project.

Staff members of the TVA provided excellent reviews for both volumes of the present report, and for this, appreciation is extended. Thanks and appreciation are also extended to Clarence G. Golueka for his review and comments on Volume II. Thanks are extended to all those who have been involved in the project for their interest and many contributions toward the successful completion of the project.

SUMMARY

The Joint U.S. Public Health Service--Tennessee Valley Authority Composting Project, Johnson City, Tennessee, began operations in June 1967. The plant ceased operations on June 30, 1971.

Studies conducted established the technical feasibility of windrow composting of municipal refuse with or without sewage sludge. Windrow temperatures of 122°F to 130°F maintained for at least seven days were shown to destroy pathogens expected in refuse and those known to be in sewage sludge. Time-temperature studies showed that windrow temperatures at the 1 1/2 foot depth averaged in excess of 140°F for two to three weeks or more. Therefore, properly practiced windrow composting was determined to be safe with respect to potential health problems from pathogenic organisms.

Sewage sludge, cow manure, paunch manure, poultry manure, animal blood, and pepper canning wastes in varying amounts were all successfully composted with municipal refuse. The addition of urea-ammonium nitrate appeared to inhibit microbial activity and resulted in a loss of nitrogen in the product. Although limestone added to the refuse appeared to aid the composting process, it also caused a loss of nitrogen.

During the project, 33,503 tons of refuse were processed in 916 days, averaging 37 tons per day. Screened compost, measured during a 12-month test period, amounted to approximately 44 percent

of the incoming refuse. During the same test period, rejects from the picking and sorting operations and compost screening amounted to 41 percent of the incoming refuse.

The quality of the compost was continually upgraded during the project. Although some glass remains after screening and this may prevent use of the compost for sale to the "carriage trade", it was acceptable for most agricultural uses and for land reclamation projects. Screened compost samples analyzed during the second period contained an average carbon to nitrogen (C/N) ratio of 28. The nitrogen content of compost used in 1969 and 1970 agricultural research projects was 1.3 percent (dry weight). During the final phases of the project, a zig-zag air classifier was partially evaluated and proved capable of removing most of the glass from screened compost.

Total plant construction costs amounted to \$960,452, not including \$61,280 for mobile equipment used in plant operations. Data in Volume I indicated actual operating costs in 1968 of \$18.45 per ton of refuse processed (at a level less than capacity) and estimated the cost at \$13.40 per ton (at full capacity) in 1969. Actual FY 1970 and 1971 operating costs were \$22.91 per ton refuse processed (8,687 tons in 222 days) and \$19.70 per ton refuse processed (10,092 tons in 232 days), respectively. Significant portions of these costs could be attributed to special projects. Based upon Johnson City

data, capital, operating, and total costs for various size windrow composting plants have been estimated (Figure A).

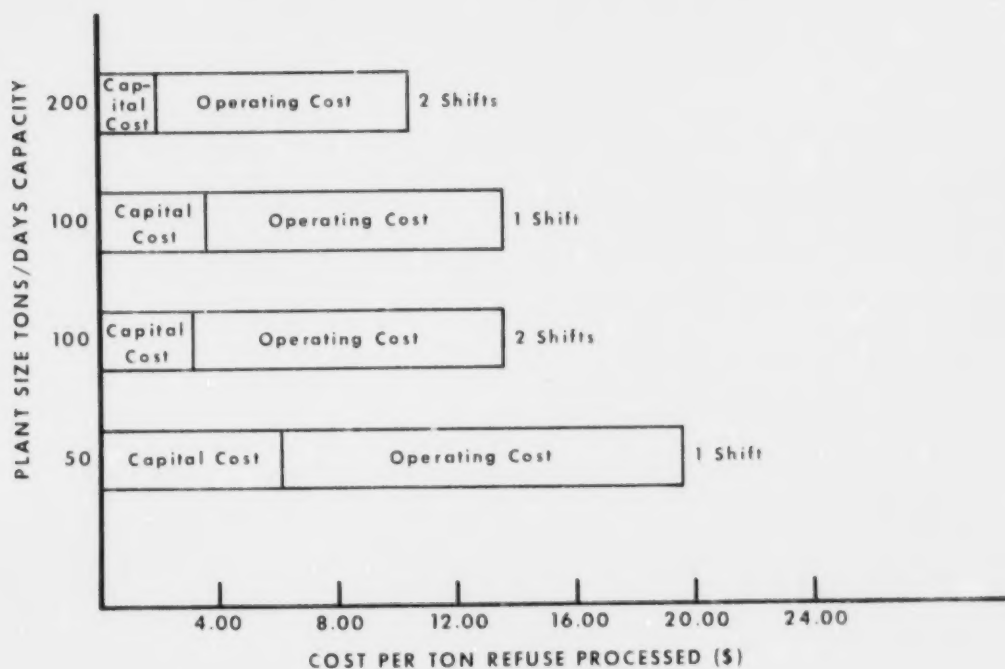


Figure A. Summary of Estimated Capital, Operating, and total costs for various size Windrow composting plants.

When compared with commercial inorganic fertilizers, unfortified composts are low in the basic nutrients (N, P, and K). Large applications of compost, however, can furnish adequate quantities of these nutrients. The compost also contains micronutrients

required for good plant growth, but the availability of these to the plant is not clear. However, the large applications of compost needed to supply adequate major nutrients may result in an accumulation of excessive concentrations of elements which may have adverse effects on soils, plants, and animals. Additional work will help to clarify this.

Significant increases in the yields of grain sorghum, corn, and bermudagrass have been obtained with compost under research conditions. The tests also showed that compost improved the physical characteristics of the soil by increasing its moisture-holding capacity and decreasing its bulk density and compression strength. Soil chemical analysis showed that pH, organic matter, K, Ca, Mg, and Zn levels were all increased by the compost, some of them from the inclusion of sewage sludge.

In corn experiments, the compost dollar value, based on yield only, was estimated at from \$1.69 per ton to \$5.80 per ton, depending upon treatments. Corn is a rather low monetary return crop. The 1969 dollar value of compost as used in forage sorghum was estimated at from \$1.10 per ton to \$2.20 per ton, depending upon treatment.

Under field demonstration conditions, the most favorable responses to compost have been with high value cash crops such as tobacco, soil reclamation and erosion control projects, and home and garden uses. Users of the compost valued it at from \$0.00 per ton to as high as \$25.00 per ton depending upon specific circumstances. The average value the users placed on the compost was

\$5.80 per ton. Since in many cases the increase in yield with compost was more than the dollar value stated by the cooperator, it is quite possible that most users stated a price they were willing to pay and not what they felt it was worth.

VOLUME I

CONTENTS

	<u>Page</u>
INTRODUCTION	1
Johnson City, Tennessee	3
Location, Climate, Population, Etc.	3
Generation and Composition of the Municipal Refuse . . .	11
USPHS-TVA Composting Project	12
Description of the Project	12
Description of the Composting Plant	16
Construction Costs	37
Modifications Made Since Startup	37
Staffing	42
Operations and Processes	44
Operating Schedule	44
Production	45
Receiving	47
Grinding	51
Addition of Sewage Sludge	57
Handling and Storage	60
Windrow Maintenance	61
Curing and Drying	63
Screening and Grinding	64
Fly Control	65
Removal of Plastics and Glass	68
PROJECT STUDIES AND INVESTIGATIONS	69
Composting Process	69
Temperature Studies	69
Effect of Windrow Turning Frequency	83
Effect of Composting Sewage Sludge with Refuse	84
Effect of Adding a Nitrogen Compound to Composting Refuse	96
Effect of Adding a Buffering Agent to Composting Refuse	101
Effect of Composting Other Wastes With Refuse	109
Effect of Covering a Windrow With Plastic Sheeting . .	118
Effect of Covering Windrows With Old Compost	121
pH Observations	123

	<u>Page</u>
Microbiological and Fly Population Studies	123
Bacteriological Statistical Experiments	123
Survival of <i>Mycobacterium phlei</i>	127
Pathogen Survival Studies Under Contract	128
Cellulolytic Activity in Composting	140
Fly Population Counts	142
Chemical and Physical Characteristics	145
Sampling Techniques	145
Moisture Content of Raw Refuse	147
Weight and Volume Losses in Composting	148
Elemental Composition of Compost	149
Analyses for Carbon/Nitrogen Ratios	149
Chemical Oxygen Demand	154
Cellulose, Starch, and Sugar Content	157
Calorific Value of Refuse and Compost	157
Cost Studies	157
Capital Cost	160
Operating Cost	160
Labor Cost	165
Cost Data Projected to Other Plants	165
Plant Income	172
Demonstration and Utilization	172
REFERENCES	181

TABLES

1	Meteorological Data for Johnson City Area	6
2	Meteorological Data for Johnson City Area Normals, Means, and Extremes	7
3	Municipal Refuse Production	13
4	Composition of Refuse	14
5	Description of Machinery and Equipment USPHS-TVA Composting Project, Johnson City	20
6	Processing Data for January 1968 through June 1969	46
7	Performance of Receiving Machinery	50

	<u>Page</u>
8 Average Performance of Rasper	52
9 Compost Fortified with Nitrogen	99
10 Aged Compost Fortified with Nitrogen	102
11 Mycobacterium Survival in Compost	129
12 Adult Fly Counts With Scudder Grill - 1967	143
13 Fly Population Data	144
14 Elements in Finished Compost	150
15 Concentration of Certain Trace Elements in Screened Compost	151
16 Nitrogen Content of Some Organic Materials and Soil	152
17 Carbon/Nitrogen Ratios of Compost Containing Additives	156
18 Construction Costs for the USPHS-TVA Windrow Composting Plant	161
19 Yearly Investment Costs for the USPHS-TVA Windrow Composting Plant	162
20 Actual Cost of Operations for the USPHS-TVA Composting Plant	163
21 Actual Annual Costs of Operating the USPHS-TVA Plant Projected to Full Capacity	164
22 Summary of Processing Costs for the USPHS-TVA Composting Plant, Johnson City, Tennessee	166
23 Salaries of TVA Personnel	167
24 Estimated Capital Costs for Windrow Composting Plants	168
25 Estimated Investment Costs for Windrow Composting Plants	169
26 Estimated Yearly Operating Costs for Various Capacity Windrow Composting Plants	170
27 Summary of Estimated Capital, Operating and Total Costs for Various Size Windrow Composting Plants	171
28 USPHS-TVA Plant Construction Costs Projected to a 50-Ton Per Day Plant	173
29 USPHS-TVA Plant Construction Costs Projected to a 100-Ton Per Day Plant	174
30 USPHS-TVA Plant Annual Operating Costs Projected to a 50-Ton Per Day Plant	175
31 USPHS-TVA Plant Annual Operating Costs Projected to a 100-Ton Per Day Plant	176
32 USPHS-TVA Plant Annual Operating Costs Projected to a 100-Ton Per Day Plant	177
33 USPHS-TVA Plant Annual Operating Costs Projected to a 200-Ton Per Day Plant	178

FIGURES

Page

1	Map of the Johnson City-Kingsport-Bristol, Tennessee Area	4
2	Average High and Low Temperatures Recorded at the Plant for the Period August 1967 through June 1971	8
3	Monthly Precipitation Recorded at the Plant for the Period August 1967-July 1969 through June 1971	9
4	Map of Johnson City, Tennessee Showing the Location of the Compost Plant	10
5	Joint USPHS-TVA Composting Project, Johnson City, Tennessee	18
6	Process Flow Diagram	19
7	Receiving Building With a 65 Cubic Yards Compaction Trailer Discharging Refuse	24
8	The Hopper in the Receiving Building	25
9	Receiving Building on the Left and Processing Building on the Right	26
10	The Picking Station Inside the Processing Building	27
11	The Hammermill Used to Shred or Grind Refuse	29
12	The Dorr-Oliver Rasper	30
13	The Permutit Dual Cell Gravity Sludge Concentrator Used to Dewater Sewage Sludge	32
14	The Cylindrical Mixer for Intimately Mixing Dewatered Sewage Sludge With the Ground or Shredded Refuse	34
15	A Windrow of Ground or Shredded Refuse	35
16	The Windrow Turning Machine	36
17	The Storing and Curing Shed (left) and Processing Building (right)	38
18	The Final Screening and Grinding Equipment	39
19	Quantity of Refuse Received at the USPHS-TVA Composting Project by Seasons	48
20	Average Temperatures at the 1-1/2-ft Depth in Windrows 1 Thru 44	70
21	Average Temperature at the 1-1/2-ft Depth in Windrows 1A Thru 34A	71
22	Average Temperatures at the 1-1/2-ft Depth in Windrows 1B Thru 34B	72
23	Average Temperatures at the 1-1/2-ft Depth in Windrows 1C Thru 34C	73
24	Average Temperatures at the 1-1/2-ft Depth of Six Selected Windrows	74
25	Temperature Profiles of a Selected Windrow During the First 11 Days of Composting	76
26	Continuous Temperature Record of Windrow 17E, 22nd to 28th Day (Station 1)	77

	<u>Page</u>
27 Continuous Temperature Record of Windrow 17E, 22nd to 28th Day (Station 2)	78
28 Temperature Profile of Windrow 17E	79
29 Temperature Profile of Windrow 17H	80
30 Temperature Profiles at the 8" Depth of Windrow 17H (Nov. 4, 1968-Dec. 30, 1968)	82
31 Temperatures in Windrows With 2 Percent Sludge Solids (1-1/2-ft Depth)	86
32 Temperatures in Windrows With 3-5 Percent Sludge Solids (1-1/2-ft Depth)	87
33 Temperatures in Windrows With 9 Percent Sludge Solids (1-1/2-ft Depth)	88
34 pH of Windrows With 2 Percent Sludge Solids (1-1/2-ft Depth)	89
35 Average pH of Windrows With 3-5 Percent Raw Sludge Solids (1-1/2-ft Depth)	90
36 pH of Windrows With 9 Percent Sludge Solids (1-1/2-ft Depth)	91
37 Temperatures of a Windrow With 34 Percent Sludge Solids (1-1/2-ft Depth)	94
38 pH of a Windrow With 34 Percent Sludge Solids (1-1/2-ft Depth)	95
39 Temperature and pH of a Windrow Containing 50 Percent Sludge Solids (1-1/2-ft Depth)	97
40 Temperature of Windrows Containing Urea-Ammonium Nitrate	100
41 Temperature of Windrows With Urea-Ammonium Nitrate	103
42 Temperatures of Windrows With Limestone and Sludge Added	105
43 pH of Windrow With Limestone and Sludge Added	106
44 Temperature of Windrow With Limestone Dust Added	107
45 pH of Windrow With Limestone Dust Added	108
46 Temperature and pH of Refuse Composted With Cow Manure	111
47 Temperature of Refuse Composted With Paunch Manure	112
48 pH of Refuse Composted With Aged Chicken Manure	114
49 Temperature and pH of Refuse Composted With Fresh Chicken Manure	116
50 Temperature of Refuse Composted With Slaughterhouse Blood	117
51 Temperature of Sludge-Refuse Mixture Composted With Pepper Canning Wastes	119
52 pH of Sludge-Refuse Mixture Composted With Pepper Canning Wastes	120
53 Average pH of Windrows 1A Thru 34A (1-1/2-ft Depth)	124
54 Average Carbon to Nitrogen Ratio of 24 Windrows Containing 3-5 Percent Sewage Sludge	153

	<u>Page</u>
55 Carbon to Nitrogen Ratio of a Windrow Without Sewage Sludge	155
56 Chemical Oxygen Demand of Composting Refuse	158
57 Sugar, Starch, and Cellulose Content of Composting Refuse	159

APPENDICES

Appendix I	183
Methods Used for Chemical Analyses	183
Appendix II	196
Statement of Operations	
Division of Reservoir Properties	196
Appendix III	203
Preliminary Results of Agricultural Research	
on Compost	203
Table 1	207
Table 2	209
Table 3	212

VOLUME II

CONTENTS

	<u>Page</u>
INTRODUCTION	213
PLANT OPERATIONS	214
Technical Staffing	214
Plant Process	215
Processing Data	216
Raw Refuse	216
Screened Compost Production	218
Rejects	218
Plant Maintenance	220
Updated Cost Data	221
Cost Accounting	221
Capital Costs	221
Operating Costs	223
Plant Income	224
SPECIAL PROJECTS	225
Grinding Study	225
Description of the Shredder	226
Summary of Results	227
Comparison of the Compost from Hammermill and Rasper Processed Refuse	227
Refuse Baling Project	233
Composting Leaves with Refuse	235
Drying the Compost	237
Screening Composted Refuse	239

	<u>Page</u>
Screening Process	239
Compost Screening Rates	244
Air Classification of Compost	245
Quality of Compost Produced at Johnson City	250
SUMMARY OF MEDICAL SURVEILLANCE	255
COMPOST UTILIZATION RESEARCH AND DEMONSTRATIONS	257
Compost Utilization Demonstrations	258
Reclaiming a Fly Ash Pond	259
Compost is Successfully Used to Grow	
Burley Tobacco	259
Compost Proves Beneficial in Growing Corn	262
Compost as an Organic Supplement for	
Horticultural Crops	266
Compost as a Mulch for Flowers, Trees,	
and Shrubs	267
Use of Compost for Establishing Grass Sod	268
Use of Compost in Reclaiming Strip-Mine Lands	269
Summary of Compost Utilization Demonstrations	272
Compost Utilization Research Projects	277
Use of Compost for Sorghum Production	278
Evaluation of Compost on Common Bermudagrass	286
Corn Grain Research Project at Johnson City	287
Summary of Compost Utilization Research Projects	290
PROJECT INTEREST AND PUBLIC RELATIONS	293
Visitors	294
Request for Information and Services	294
PROJECT TERMINATION	295
REFERENCES	298

TABLES

1	Production of Screened Composted Refuse and Rejects	219
2	Construction and Equipment Costs for the PHS-TVA Windrow Composting Plant	222
3	Weight Loss per Hammer Set	228
4	Power Consumption During Grinding Experiment	229
5	Cost of Material Ground, Dollars	230
6	Comparison of Compost Produced from Rasper Ground Refuse to Compost Produced from Hammermill Ground Refuse	232
7	Carbon to Nitrogen Ratio of Compost from Vibrating Screen and Rotary Screen	242
8	Results of Initial Operational Testing of Zig-Zag Air Classifier	247
9	Chemical Characteristics of Johnson City and West German Compost	252
10	Ultimate Analysis of Johnson City and German Composts	253
11	Forage Sorghum Yield and N Uptake at Muscle Shoals, as Affected by Compost and N Rates	280
12	Effect of Compost and N on Nutrient Concentration in Forage Sorghum, Muscle Shoals	283
13	Effect of Compost and N on Physical and Chemical Characteristics of Soil at Muscle Shoals	285
14	Common Bermudagrass Yield, as Affected by Compost and N, Muscle Shoals	288
15	Response of Corn to Compost, Johnson City Experiment	291

FIGURES

1	Seasonal Variation in the Quantity of Refuse Received	217
2	Internal Temperature at 18-inch Depth of Grinding Study Test Windrows	234
3	Grain Dryer Used to Dry Unscreened and Screened Composted Refuse	238
4	Grain Dryer Drying Unscreened Composted Refuse	238
5	Screening Process Used to Screen the Composted Refuse	240
6	Composted Refuse After Passing Through the Vibrating Screen	243

	<u>Page</u>
7 Composted Refuse After Passing Through the Rotary Screen	243
8 Fly Ash Pond Reclamation Project Before Reclamation	260
9 Fly Ash Pond Reclamation Project After Reclamation	260
10 Corn Grain Research Project, Johnson City, Tennessee (Photograph sows control)	264
11 Corn Grain Research Project, (Photograph shows plot receiving complete fertilizer treatment but no compost	265
12 Corn Grain Research Project, (Photograph shows plot receiving 100 tons per acre of compost but no nitrogen fertilizer)	265
13 Compost Demonstration on a TVA Reservation (Boone Dam)	270
14 Compost Demonstration at a Municipal Park in Jonesboro, Tennessee	270
15 Compost Demonstration at a Bottling Plant in Johnson City, Tennessee	271
16 Compost Demonstration at the Tri-Cities Airport	271
17 "Cane Patch" Strip Mine Demonstration at Norton, Virginia	273
18 "Cane Patch" Strip Mine Compost Demonstration at Norton, Virginia	273
19 Experimental Strip Mine Reclamation Project	274
20 Experimental Strip Mine Reclamation Project	274
21 Compost Spreader	276
22 Three-year Total Sorghum Yield and N Uptake as Affected by Compost and N Rates	282
23 Three-year Average Corn Yield, as Affected by Compost and N Application	292

APPENDICES

Appendix I	300
Statement of Operations (Division of Reservoir Properties), June 1970	300
Statement of Operations (Division of Reservoir Properties), June 1971	307
Appendix II	312
Technical Report on Johnson City Baling Experiment	312

	<u>Page</u>
Appendix III	326
Visitors to Composting Project	326
States, Foreign Countries	326
Groups	327
Request for Information on Composting	329
Foreign	329
Journals and Publications	329
Universities and Colleges and Other Schools	329
Congressmen and Legislators	331
United States (Individuals)	331
Consultants	332
Organizations	333

JOINT USEPA-TVA COMPOSTING PROJECT, JOHNSON CITY, TENNESSEE

Volume I
WITH OPERATIONAL DATA
June 1967 - September 1969

INTRODUCTION

The natural phenomenon of the degradation of wastes by microbiological activity has been utilized by agriculturists for centuries to produce humus. In modern times the stress upon the environment caused by wastes and the need to replenish the organic constituents removed from soils by intensive farming have created an interest in large-scale composting.*

In Europe, large-scale composting has received attention because of its possibilities for supplying organic material for the soil and a considerable number of plants have been operated successfully over the last twenty-five years. In America, where there has been a different attitude toward the conservation of resources and where the need for the replenishment of organics in the soil has been less acute, composting has only recently received attention, and here the greatest emphasis has been on its use as a method of waste disposal.¹

In the United States, the University of California studied the composting of municipal wastes from 1950 to 1952.² One conclusion of this study was that composting offered an alternative method of refuse disposal that would help alleviate the growing difficulty of finding landfill sites

*Mention of commercial products or processes throughout this report does not imply endorsement by the U.S. Government.

and problems of air pollution that result from incineration. However, Wiley and Kochtitsky concluded that the inability to dispose of large quantities of compost at a favorable price was probably a major factor in the closing of six of nine plants during the period 1962 to 1964.³ In addition to a lack of marketing knowledge, there was a dearth of reliable cost data. Certain environmental and public health aspects also required study in the United States.

In the early 1960's, F. E. Gartrell of the Tennessee Valley Authority (TVA) proposed a full-scale composting project to be jointly sponsored by TVA, the U.S. Public Health Service (USPHS), and a municipality in the Tennessee Valley. Both USPHS and TVA were interested in a sanitary method of waste disposal and TVA was also interested in the use of compost for soil improvement. In March 1963, the Division of Agricultural Development, TVA initiated a project called "The Use of Municipal and Industrial Organic Waste in the Production of Soil Amendments and Fertilizers." The compost plant was to investigate the process as a method for disposing of wastes and at the same time reclaiming waste for the benefit of the land.

In August 1964, the USPHS and the TVA agreed upon a joint research and demonstration project for composting solid wastes and sewage sludge. In November 1964, USPHS detailed John S. Wiley to the Division of Health and Safety, (now the Office of Health and Environmental Science) TVA, to collaborate in the detailed planning of the project. Under the agreement, TVA would have financed and constructed the composting plant. When the Solid Waste Disposal Act was passed in October 1965, the Bureau of Budget directed that the proposed plant be financed from funds available under

the terms of the Act to the Department of Health, Education, and Welfare. Johnson City had been selected as the site for the composting project on the basis of two surveys of six Tennessee Valley area cities. One survey, conducted by TVA engineers and representatives of state and local health departments, covered disposal of refuse and sewage sludge. The other, made by TVA agricultural specialist, investigated the use of chemical and organic fertilizers in the vicinity of these cities. On February 15, 1966, the two agencies and Johnson City, Tennessee, signed a cooperative agreement for the construction and operation of the "Joint USPHS-TVA Composting Project, Johnson City, Tennessee." Ground was broken for the plant on May 18, 1966; construction was completed and the plant was put in operation on June 20, 1967.

Johnson City, Tennessee

Location, Climate, Population, Etc. Johnson City, in Washington County, is in the extreme northeastern corner of Tennessee at longitude 82° 21' W., latitude 36° 19' N. (Figure 1). It lies near the junction of the Watauga River and the South Fork Holston River in the headwaters of the Tennessee River system. The terrain immediately surrounding the city ranges from gently rolling on the east and south to very hilly on the west and north. Mountain ranges begin about 5 miles to the southeast and about 20 miles to the west and north, with many peaks rising to 4,000 and some to 6,000 ft above sea level toward the southeast in the Appalachian system. Elevations in the city range from 1,500 to over 1,700 ft.

The Johnson City area does not lie directly within any of the principal storm tracks that cross the country, but comes under the influence of



Figure 1. Map of Johnson City-Kingsport-Bristol, Tennessee area.

storm centers that pass along the Gulf Coast and then up the Atlantic Coast toward the northeast. Table 1 gives meteorological data for the calendar years 1967 and 1968, for the Bristol, Tennessee, station of the U.S. Weather Bureau at the Tri-City Airport, 9 miles northwest of the USPHS-TVA Composting Project plant. Table 2 gives the normals, means, and extremes for this station. Since August 1967, temperature and rainfall records have been kept at the composting plant. Figure 2 shows the recorded average high and low temperatures for the months through June 1971*. Figure 3 shows the monthly rainfall recorded at the plant over the same period.

Johnson City, with an area of 15 square miles (Figure 4), had in 1969, an estimated population of 35,300. The city and county had an estimated population of 68,500. The trading area had an estimated population of 180,000 and the area within a 50-mile radius had an estimated population of 635,000.

The average income per family in Johnson City was \$8,482 in 1968. About 36 percent are employed in manufacturing, the remainder in trade, finance, government, transportation, service jobs, etc. In the rural area, about 28 percent occupy farms. Of this population, 30 percent are engaged in manufacturing. Washington County has about 3,000 farms, averaging 55 acres each.

Tobacco is the most important crop of the area. Corn and some small grains are grown in support of the important dairy industry. Raising of beef cattle has increased in the last 20 years to become a significant part of the economy.

In the seven counties of the area, there are about 320,600 acres of cropland and 281,800 acres of pasture.

*Original figures updated to include period covered in Volume II.

TABLE 1

METEOROLOGICAL DATA FOR JOHNSON CITY AREA

Tri-City Airport (Bristol, Tennessee, station), latitude 36° 29' N., longitude 82° 24' W., ground elevation 1507 feet above sea level.

Month	Temperature				Precipitation				Relative humidity				Wind				Number of days				Temperatures							
	Average		Extremes		Total		Snow		Standard		Time used		Direction		Speed		Sunshine to sunset		Precipitation		Thunderstorms		Heavy fog		Maximum		Minimum	
	Daily	Monthly	Daily	Lowest	Daily	Lowest	Daily	Lowest	Daily	Monthly	Daily	Monthly	Daily	Monthly	Daily	Monthly	Partly	Cloudy	Cloudy	0.1 inch or more	1.0 inch or more	Thunderstorms	Heavy fog	30 and above	32 and below	32 and below	0 and below	
JAN	46.4	47.0	72.4	14.0	0.75	0.75	0.0	0.0	19	82	86	63	69	24	2.7	5.4	9	14	8	1	0	0	1	0	1	0	1	0
FEB	48.9	49.7	67.1	11.0	0.75	0.75	0.0	0.0	17	76	79	62	63	27	6.4	7.2	10	16	4	1	0	0	0	0	0	0	0	0
MAR	50.8	50.2	79.2	15.0	1.01	1.01	0.0	0.0	20	76	81	68	52	28	5.0	7.5	15	16	4	0	0	0	0	0	0	0	0	0
APR	51.2	51.7	81.1	16.0	2.89	2.89	0.0	0.0	0	96	96	67	70	28	1.6	0.2	32	29	8	0	0	0	0	0	0	0	0	0
MAY	59.6	58.7	85.7	24.0	2.14	2.14	0.0	0.0	0	91	93	62	68	07	1.3	0.7	13	10	0	0	0	0	0	0	0	0	0	0
JUN	60.3	57.0	88.7	27.0	0.68	0.68	0.0	0.0	0	95	96	75	75	1.5	0.5	11	10	0	0	0	0	0	0	0	0	0	0	0
JUL	79.4	67.8	87.2	48.0	2.08	2.08	0.0	0.0	0	91	96	68	77	3.6	0.4	3.9	15	27	10	0	0	0	0	0	0	0	0	0
AUG	81.4	70.7	87.3	51.0	1.29	1.29	0.0	0.0	0	92	95	56	71	1.3	0.6	2.9	31	21	10	0	0	0	0	0	0	0	0	0
SEP	76.6	68.6	80.0	27.0	1.99	1.99	0.0	0.0	0	86	95	55	64	3.6	0.7	6.5	18	25	25	0	0	0	0	0	0	0	0	0
OCT	63.5	51.6	73.1	17.0	1.03	1.03	0.0	0.0	1	79	85	53	60	3.3	0.9	5.1	10	13	9	0	0	0	0	0	0	0	0	0
NOV	51.3	40.8	71.2	14.0	3.73	3.73	0.0	0.0	2	78	85	47	74	3.3	0.9	5.1	10	13	9	0	0	0	0	0	0	0	0	0
DEC	45.7	42.6	68.1	17.0	4.27	4.27	0.0	0.0	19	85	89	60	66	2.8	1.5	5.4	35	25	7	0	0	0	0	0	0	0	0	0
YEAR	63.7	54.2	88.1	17.0	24.08	24.08	0.0	0.0	19	85	89	60	66	2.8	1.5	5.4	35	25	7	0	0	0	0	0	0	0	0	0
JAN	43.5	44.2	62.1	11.0	0.95	0.95	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
FEB	45.5	46.1	64.1	11.0	0.95	0.95	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
MAR	47.5	48.1	66.1	13.0	1.54	1.54	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
APR	49.5	50.1	68.1	15.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
MAY	51.5	52.1	70.1	17.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
JUN	53.5	54.1	72.1	19.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
JUL	61.5	62.1	80.1	27.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
AUG	63.5	64.1	82.1	29.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
SEP	65.5	66.1	84.1	31.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
OCT	67.5	68.1	86.1	33.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
NOV	69.5	70.1	88.1	35.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
DEC	71.5	72.1	90.1	37.0	2.14	2.14	0.0	0.0	12	78	81	63	68	01	0.9	5.7	24	13	13	0	0	0	0	0	0	0	0	0
YEAR	63.7	54.2	88.1	17.0	24.08	24.08	0.0	0.0	19	85	89	60	66	2.8	1.5	5.4	35	25	7	0	0	0	0	0	0	0	0	0

Unless otherwise indicated, directional units used in this bulletin are: temperature in degrees F., precipitation, including snowfall, in inches, wind maximum in miles per hour, and relative humidity in percent. Degree day totals are the sum of the negative departures of average daily temperatures from 65°F. and are included in annual totals beginning with July 1st. Heavy fog, visibility less than 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average (clouds 0-3, partly cloudy 4-7, and cloudy days 8-10).

Figures listed in a direction column indicate direction in degrees from true North, i.e., 00, East, 90, South, 180, West, 270, and 360. Rainfall is the vector sum of the number of days on which rain fell and the number of inches of rain. The direction column is not used for the number of days on which rain fell. Figures are based on actual observations.

TABIE 2

METEOROLOGICAL DATA FOR JOHNSON CITY AREA

NORMALS, MEANS, AND EXTREMES

Tri-City Airport (Bristol, Tennessee, Station), latitude 36° 29' N., longitude 82° 24' W., ground elevation 1507 feet above sea level.

Month	Temperature				Precipitation				Relative humidity				Wind &				Mean number of days			
	Normal		Extremes		Normal		Extremes		Standard time used		Mean hourly		Speed		Direction		Surf		Mean sky cover	
	Maximum	Minimum	Record high	Record low	Maximum	Minimum	Record high	Record low	AM	PM	7	7	7	7	7	7	7	7	7	7
Jan	48.4	28.7	78.1	-15.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Feb	50.0	30.1	78.1	-15.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Mar	58.5	35.5	88.0	-4.0	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Apr	68.5	45.7	92.1	18.5	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
May	77.6	53.7	92.1	30.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Jun	84.5	61.9	92.1	38.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Jul	85.4	62.4	92.1	40.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Aug	80.4	57.5	92.1	38.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Sep	70.1	45.9	88.0	18.5	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Oct	58.7	35.1	80.1	15.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Nov	47.1	25.5	75.1	-9.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7
Dec	47.5	28.1	75.1	-15.1	4.9	1.8	19.7	-19.7	7	7	7	7	7	7	7	7	7	7	7	7

For period May 1961 through the current year. Means and extremes in the above table are from the existing or comparable location(s). Annual extremes have been exceeded at other locations as follows. Highest temperature 102 in July 1952.

Length of record, years. (a) Data on temperature and precipitation for the period 1951-1961. (b) Data on temperature and precipitation for the period 1951-1961. (c) Data on temperature and precipitation for the period 1951-1961. (d) Data on temperature and precipitation for the period 1951-1961. (e) Data on temperature and precipitation for the period 1951-1961. (f) Data on temperature and precipitation for the period 1951-1961. (g) Data on temperature and precipitation for the period 1951-1961. (h) Data on temperature and precipitation for the period 1951-1961. (i) Data on temperature and precipitation for the period 1951-1961. (j) Data on temperature and precipitation for the period 1951-1961. (k) Data on temperature and precipitation for the period 1951-1961. (l) Data on temperature and precipitation for the period 1951-1961. (m) Data on temperature and precipitation for the period 1951-1961. (n) Data on temperature and precipitation for the period 1951-1961. (o) Data on temperature and precipitation for the period 1951-1961. (p) Data on temperature and precipitation for the period 1951-1961. (q) Data on temperature and precipitation for the period 1951-1961. (r) Data on temperature and precipitation for the period 1951-1961. (s) Data on temperature and precipitation for the period 1951-1961. (t) Data on temperature and precipitation for the period 1951-1961. (u) Data on temperature and precipitation for the period 1951-1961. (v) Data on temperature and precipitation for the period 1951-1961. (w) Data on temperature and precipitation for the period 1951-1961. (x) Data on temperature and precipitation for the period 1951-1961. (y) Data on temperature and precipitation for the period 1951-1961. (z) Data on temperature and precipitation for the period 1951-1961.

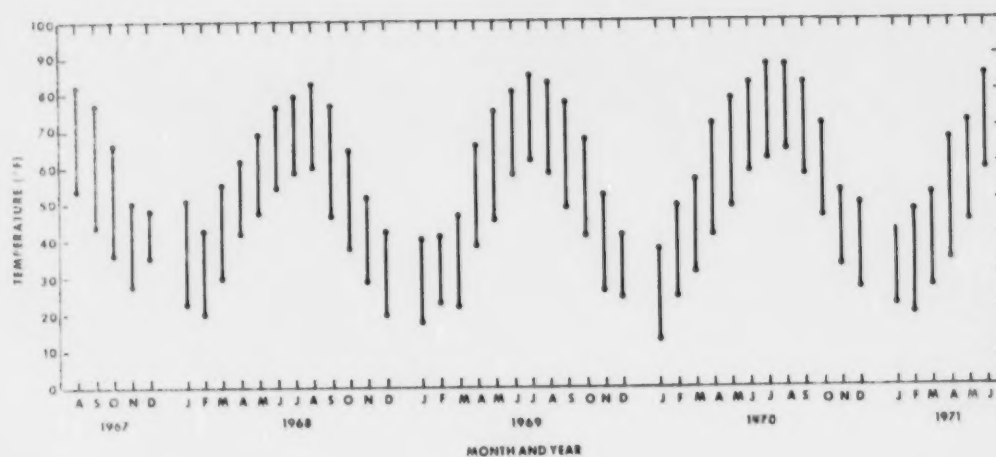


Figure 2. Average monthly high and low temperatures recorded at the plant for the period August 1967 through June 1971.

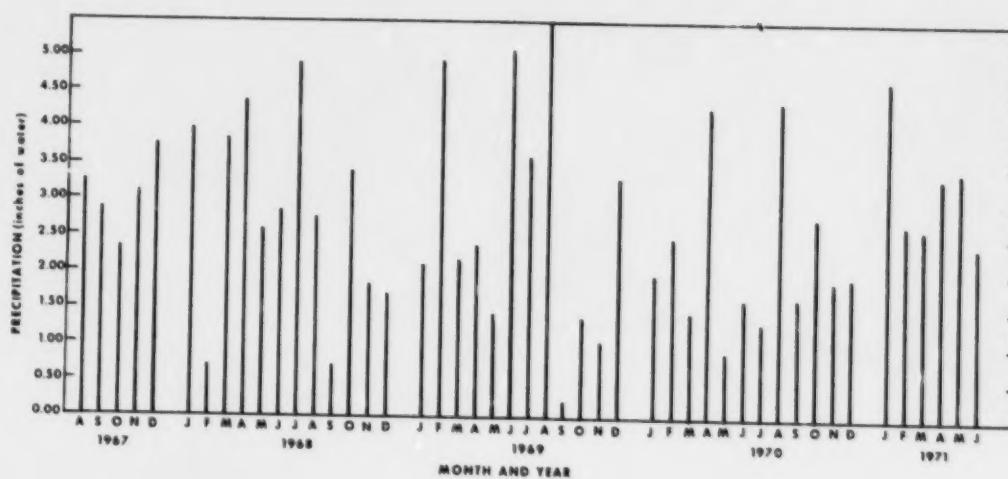


Figure 3. Monthly precipitation recorded at the plant for the period, August 1967 through June 1971.

Generation and Composition of Municipal Refuse. Residential wastes of 31,200 persons and 40 percent by weight of the commercial wastes are collected weekly in Johnson City by the Sanitation Department using five three-man crews with compactor trucks. Sixty percent of the homeowners, however, burn some wastes in their backyards. Others employ private collectors to provide supplemental service once a week. Street sweeping and brush are collected by the Street Department and are deposited in the city's landfill.

Industries in Johnson City generate about 130 tons of solid wastes weekly. The majority of these are hauled to disposal sites by employees of the industries. The Sanitation Department collects from seven industries, totalling about 9 tons per week.

Wastes collected by the Sanitation Department are delivered to a transfer station. Here they are transferred to either a 53 or a 65 cu yd compaction trailer for hauling to the compost plant or the landfill. One load per day of commercial material, about 95 percent paper, and averaging about 10 tons, is routinely hauled to the landfill. Hospital wastes and some yarn wastes from an industrial establishment also do not reach the composting plant. When the compaction trailers are out of service for any reason, the 16 cu yd packer trucks used for residential collection deliver their refuse to the composting plant.

For the period January 1968 through June 1969, the compost plant received an average of 33.8 tons of refuse per day for 5 days per week. This collection with the 10 tons per day sent directly to the landfill, is about 2.8 lb per capita per day on a 5-day-week basis and 2 lb per capita on the 7-day-week basis. The low figure probably does not

represent the true per capita generation of refuse in Johnson City.

Two studies of the production of refuse per capita and the composition of that refuse have been made in the same residential area of Johnson City. The first was performed by the Division of Technical Operations, Bureau of Solid Waste Management, in October 1967, and the second by the staff at Johnson City in July 1968.

The first study showed a production rate of 1.1 lb per capita per day of residential waste and the second showed a rate of 1.4 lb per capita per day (Table 3).

The composition of these samples was found by manually sorting the refuse into ten categories (Table 4). This refuse was higher in food wastes and lower in paper wastes than the averages usually reported since it was collected from a residential district. The refuse received daily at the Johnson City plant probably has a greater paper content. As previously mentioned, one load of commercial waste, with a very high paper content, is not received at the compost plant but is hauled directly to the landfill.

USPHS-TVA Composting Project

Description of the Project. The joint USPHS-TVA Composting Project has been for demonstration and research to study the feasibility of composting as a possible answer to the problem of increasing quantities of municipal solid wastes produced by municipalities. The major responsibilities of the principals are as follows:

TABLE 3
MUNICIPAL REFUSE PRODUCTION
Johnson City, Tennessee
(Residential Area)

	October 1967	July 1968
Refuse production (lb/capita/day)	1.1	1.4
Number of homes sampled	136	144
Population sampled	519.8	550.0
Population density (people/home)	3.82*	3.82*
Weight of refuse collected, lb (wet weight basis)	4,003	5,400
Sample period, days	7	7

*Based on 1967 study.

TABLE 4
COMPOSITION OF REFUSE
Johnson City, Tennessee

Category	<u>Wet weight, pounds</u>		<u>Percent of total sample</u>	
	October 1967	July 1968	October 1967	July 1968
Paper products	1,820.4	794.5	45.5	34.9
Food wastes	1,036.5	788.5	29.5	34.6
Metals:				
Ferrous		211.5		9.3
Nonferrous		24.5		1.1
Combined	433.0	236.0	10.8	10.4
Glass products	436.1	206.0	10.9	9.0
Plastics	67.0	76.5	1.7	3.4
Leather and rubber	40.0	55.5	1.0	2.4
Yard wastes	63.5	53.0	1.6	2.3
Cloth and synthetics	56.0	47.0	1.3	2.0
Brick, rock, dirt, etc.	39.0	3.5	1.0	0.2
Wood	<u>11.5</u>	<u>18.5</u>	<u>0.3</u>	<u>0.8</u>
Total	4,003.0	2,279.0	100.0	100.0

1. USPHS pays all costs incurred in the design, construction, operation, and maintenance of the plant and conducts research related to the process of composting, the nature of compost, the health aspects of compost, and the efficient operation of the composting plant.

2. TVA designs, constructs, operates, and maintains the compost plant and conducts research on the feasibility of commercial and agricultural use of the compost produced, on a reimbursable basis.

3. The city of Johnson City provides the site for the plant, mixed refuse from its collection system, and raw or digested sewage sludge from its sewage treatment plant.

While TVA operates and maintains the composting plant, USPHS has the responsibility for technical direction, which includes developing schedules for certain operations, monitoring the physical and chemical characteristics of the maturing compost, and altering schedules and procedures where these characteristics dictate such changes. The USPHS is studying plant operation and sanitation methods to avoid the production of odors and the propagation of flies and rodents and, in close collaboration with the TVA agriculturist assigned to the project is studying the improvement of composting methods and compost. East Tennessee State University, under contract with USPHS, and a microbiologist on the project staff, studied the survival of pathogens throughout the composting and curing periods.

As part of the feasibility study, USPHS and TVA are studying the economics of the plant operation on the basis of detailed cost records that TVA maintains.

Since TVA operates the National Fertilizer Development Center (NFDC) at Muscle Shoals, Alabama, one of the world's largest institutions for research and development of fertilizer, TVA has important resources for testing and demonstrating the value of compost as a soil amendment and for studying the marketing of compost. The principal use of compost is expected to be as a soil builder and conditioner with potential for application on lawns, gardens, parks, golf courses, and truck or specialty farms. Tests may show how compost fortified with nitrogen, phosphorus, and potassium can be used to produce an organic-base fertilizer. Disposal of the compost has been a major factor in the success or failure of many composting plants. Marketing, therefore, should be an integral part of the demonstration project and the study of the economics of composting.

The Division of Agricultural Development, TVA, has a number of test plots and demonstrations under study by the project agriculturist in the Johnson City area. Test plots have also been established at the NFDC, Muscle Shoals, Alabama. Such factors as the rate of application and effect of compost, on various crops, etc., are being studied. Greenhouse studies will be made, and some work has been started with the use of compost on bare areas, such as abandoned strip mines and highway cuts, for revegetation and erosion control.

Description of the Composting Plant. The composting plant began operating on June 20, 1967, to demonstrate composting of municipal solid wastes by the windrow method.

The plant was designed to process during a 5-day-week raw refuse and sewage sludge of 33,000 people, approximately the present population of Johnson City. Nominal capacity is 60 tons per day for an 8-hr shift.

Figure 5 shows an overall view of the plant. Figure 6 is a schematic layout of the processing steps, and Table 5 lists the plant equipment and specifications.

Refuse is delivered to the plant, 5.4 miles distant, in 53 and 65 cu yd compaction trailers from a central transfer station in Johnson City. The refuse is weighed and then dumped into a hopper in the receiving building or onto the paved apron to be later moved into the hopper by a front-end loader (Figures 7 and 8). Items such as mattresses, bed springs, bicycle frames, wire, which might block or entangle the equipment, are removed. A 6-ft wide plate conveyor, forms the bottom of the hopper and advancing at a rate of 2 to 10 ft per minute, carries the refuse under a vertical leveling gate and drops it onto a 3-ft wide elevating belt that carries it into the processing building. The receiving building is roofed and enclosed on three sides. The belt conveyor is covered between the receiving and the processing buildings (Figure 9).

The processing building is 40 ft by 60 ft and houses all of the refuse processing operations, the sludge thickener, and the refuse-sludge mixer. The elevating belt conveyor from the receiving building becomes horizontal after it enters the upper level of the processing building. It carries the refuse past a picking station at a rate of 60 ft per min (Figure 10). Two or more pickers manually remove bulky paper, rags, glass, plastics, metals, and other noncompostable material. The refuse placed in paper or plastic bags may arrive at this point with the bag still intact. Either the pickers must discard the entire bag or permit



Figure 5 - Joint USPHS-TVA Composting Project
Johnson City, Tennessee

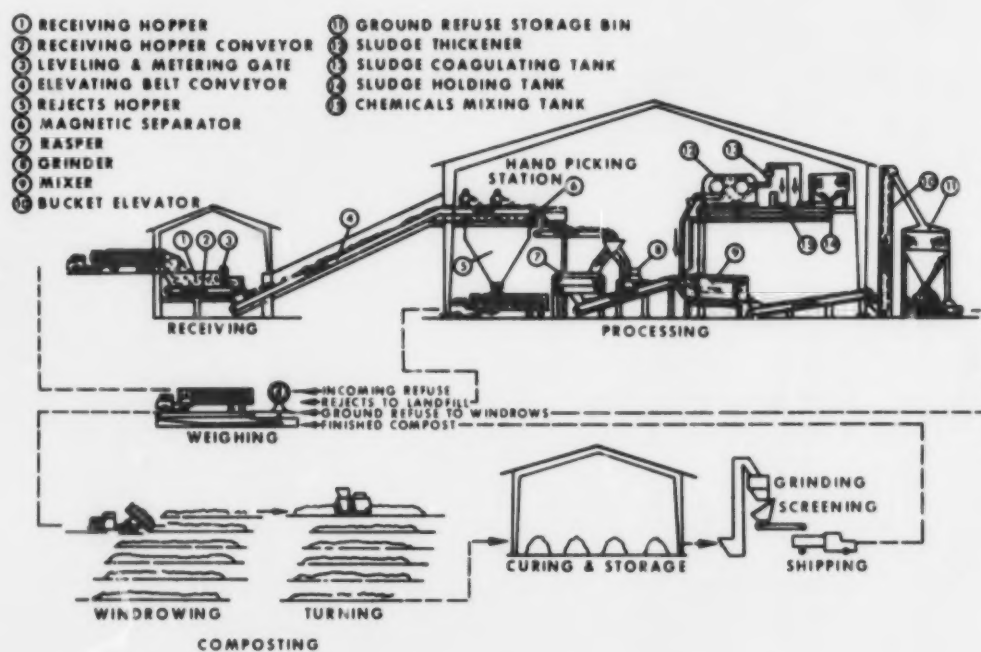


Figure 6. Process Flow Diagram

TABLE 5

DESCRIPTION OF MACHINERY AND EQUIPMENT
USPHS-TVA COMPOSTING PROJECT, JOHNSON CITY

Item	Description	Manufacturer & model	Capacity	Power Rating
Truck scale	Mechanical 10 x 34-ft platform scale with tare beam and remote dial weighs incoming refuse.	Fairbanks, Morse, Inc. Model 6507B	30 tons	
Refuse feeder and leveling grate	Double-beaded 5 x 28-ft apron feeder in bottom of hopper (fabricated at plant) moves refuse at 2-10 ft/min; vertical, hydraulically controlled leveling grate regulates flow of refuse.	Websters Mfg., Inc. Feeder and grate driven by Falk helical-gear speed changers, models 51BN2 and 224F2, respectively.	10 tons/hr	5 hp
20 Raw refuse elevating conveyor	Rubber-covered belt 3-ft wide moves raw refuse at 60 ft/min from receiving building to processing building under cover and then to picking station. Head pulley is permanent magnet (field: 400 Gauss, 5 in. from face at center) for removing ferrous metal.	Continental Conveyor and Equipment Co.	10 tons/hr	2 hp
Raw refuse cross conveyor	Rubber-covered belt 3-ft wide moves refuse at 60 ft/min from picking station to grinders.	Continental Conveyor and Equipment Co.	7.5 tons/hr	1 hp
Rasping machine	Arms on rotating vertical shaft force refuse against rasping pins projecting from sides and bottom of 18-ft-diameter housing until reduced to less than 2-in. particles that drop through perforated steel floor.	Dorr-Oliver N.V., Amsterdam. Type R.T.M. 55 V.S.T.D.	7 tons/hr	40 hp each, 2 motors
Hammermill	Mill with 44 chisel-point swing hammers (21 lb each) reduces refuse to particles that pass grate openings 2 in. by 1.5 to 2.5 in.	Gruendler Crusher and Pulverizer Co.	12 tons/hr	250 hp

TABLE 5 (continued)

Item	Description	Manufacturer & model	Capacity	Power Rating
Ground refuse cross conveyor	Rubber belt 2.5 ft wide moves ground refuse from hammermill to ground refuse conveyor.	Fabricated by TVA	7.5 tons/hr	1 hp
Ground refuse conveyor	Rubber belt 2 ft wide moves ground refuse from rasper to mixer at 200 ft/min.	Continental Conveyor and Equipment Co.	7.5 tons/hr	1.5 hp
Sludge concentrator	Electric-motor-driven stationary sewage sludge concentrator, traveling screen type, utilizing gravity as the dewatering driving force. The nylon filter cloth moves at a variable speed of 1.5 to 4.5 fpm. The unit is designed to dewater raw sewage sludge containing 3 to 5 percent solids and deliver a sludge cake with approximately 15 percent solids. In addition to the filter, there is a Wallace & Tiernan flocculant dosing pump and a Worthington metering pump of the diaphragm type.	Permutit Co. Model DCG-200	Designed for 1200 gal/hr	
Refuse-sludge mixer	Rotary drum mixer, 3 ft in diameter and 10 ft in length. Internal vanes are designed for mixing the refuse and sludge and discharging mixture at outlet.	Designed and fabricated by TVA		
Conveyor for ground refuse-sludge mixture	Moves mixed refuse and sludge from mixer to bucket elevator. Rubber belt type, 2 ft wide.	Continental Conveyor & Equipment Co.	Rated at 890 cu ft/hr or 11.3 tons/hr at belt speed of 200 ft/min	1 hp

TABLE 5 (continued)

Item	Description	Manufacturer & model	Capacity	Power Rating
Conveyor for ground refuse-sludge mixture	Replaces sludge-ground refuse mixer when mixer is not in use. Belt is 2 ft wide and 15 ft long.*	Fabricated by TVA		1 hp
Conveyor for dis- charge of ground refuse	Used to transfer ground refuse to trucks when bucket elevator and storage hopper not used. Belt is 2 ft wide and 25 ft long.	Fabricated by TVA		2 hp
Bucket elevator	Vertical centrifugal type. Electric-motor- driven. Buckets are cast malleable iron, 14 x 7 in., 16 in. on center. Elevator used to transfer ground refuse to storage bin.	Fairfield Engineering Co. Model VCE, No. 147	Rated at 1650 cu ft/ hr (75% of theoretical) at chain speed of 200 ft/min	3 hp
Storage bin	Cylindrical storage bin designed to hold several truckloads of ground refuse. Discharge to truck through horizontal sliding gate. Bin is 12 ft in diameter at largest dimension.	Designed and fabricated by TVA	About 110 cu yd	
Bucket elevator	Electric-motor-driven, vertical bucket, centrifugal discharge type. Used in moving compost from feed hopper to vibrating screen.	J. B. Ehrsam and Sons Mfg. Co. H-17	Rated at 1715 cu ft/ hr (75% of theoretical) at chain speed of 221 ft/min	3 hp
Vibrating screen	Electric-motor-operated. Vibrating in- clined screen with interchangeable wire mesh screens of 1/4- and 1/2-in. openings. Used to screen the compost.	Link Belt		

TABLE 5 (continued)

Item	Description	Manufacturer & model	Capacity	Power Rating
Compost grinding hammermill	Swing hammer type with 30 hammers each weighing approximately 2-3/4 lb. Electric-motor-driven, heavy duty type. Used to regrind compost.	J. B. Sedberry, Inc. 5W-26	10 tons/hr rated, did not grind compost at this rate.	100 hp
Windrow turner	Diesel-engine-driven, self-propelled. A rotating drum turns the windrow as the machine straddles the row. The drum has teeth arranged so as to move the material toward the center of the windrow as it is turned. The material is picked up from the ground, passed over the drum and redeposited behind the machine. The machine moves through the row at approximately 0.27 mph and is capable of turning windrows approximately 8-ft wide and 5-ft high.	General Products of Ohio, Inc. (Cobey) Model 003	500 tons/hr (spec. claim 122 BHP) 1500 tons/hr by specs) of 700-lb/cu yd material)	100 hp +
Tractor shovel	Rubber-tired, gasoline-engine-driven front-end loader with general purpose bucket transports refuse, ground refuse, and compost.	International Harvester Company, Model H-50 (Ser. C)	Lifting: 13,200 lb Bucket: Heaped: 3-1/2 cu yd Struck: 3 cu yd	103 bhp at 2,500 RPM

*In late 1969 the mixer was found to be too small for the capacity of the new Gruendler hammermill. As sludge was not being processed, the mixer was temporarily removed and replaced by this conveyor.

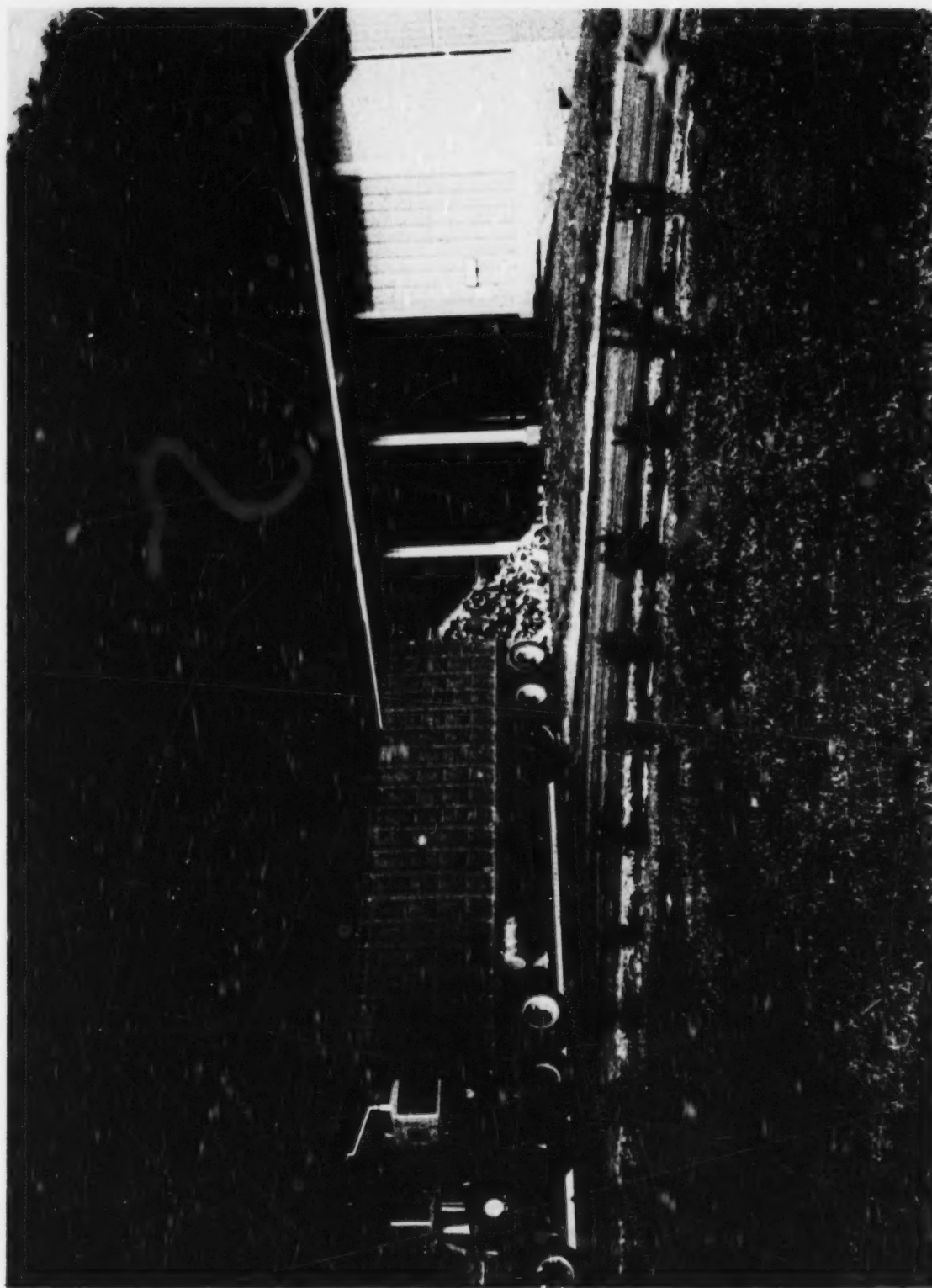


Figure 7 - Receiving building with a 65 cubic yards compaction trailer discharging refuse.



Figure 8 - The hopper in the receiving building. Refuse is being wetted in preparation for shredding in the rasper.

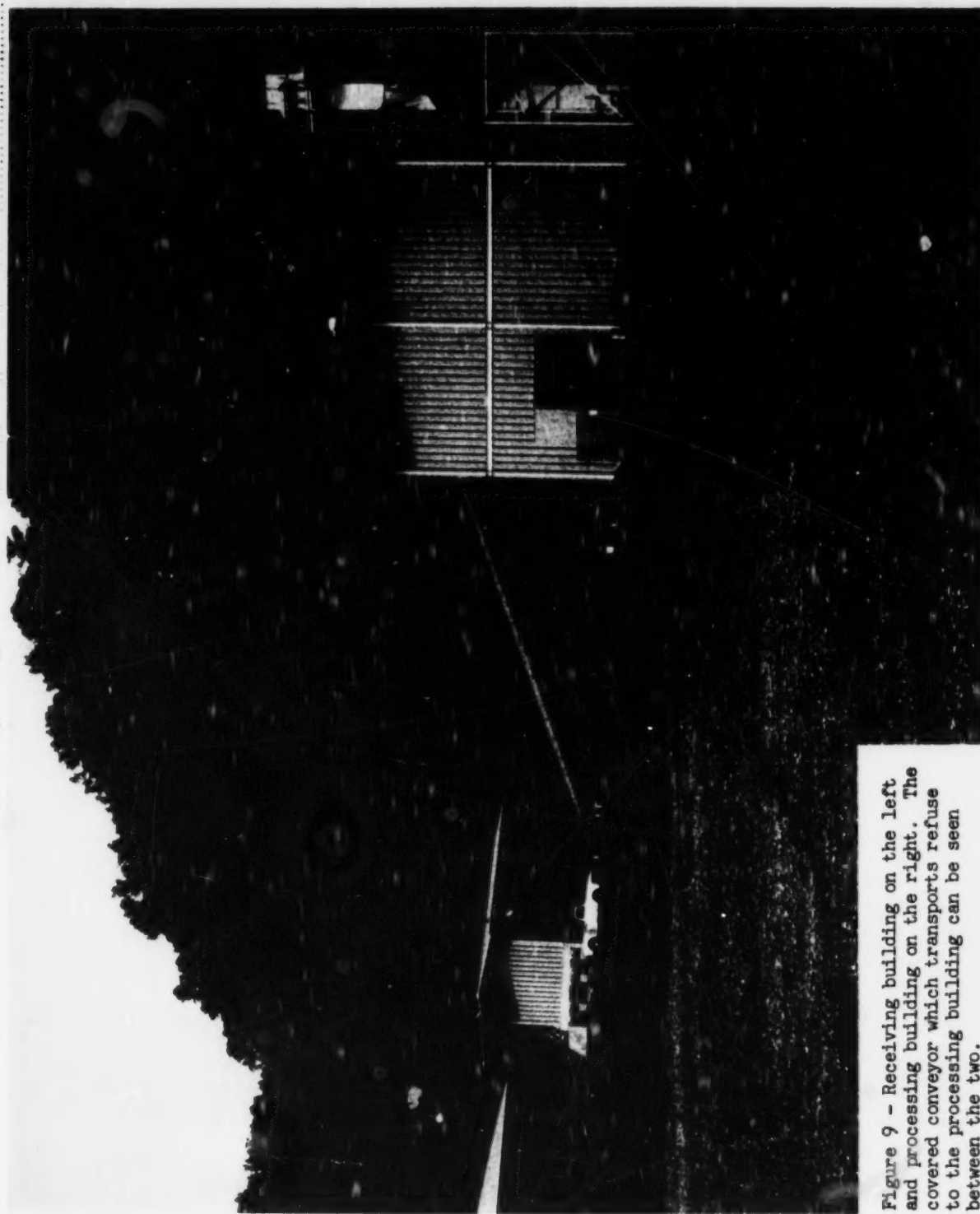


Figure 9 - Receiving building on the left and processing building on the right. The covered conveyor which transports refuse to the processing building can be seen between the two.



Figure 10 - The picking station inside the processing building. The men are attempting to remove noncompostable items and large items which might damage equipment.

some cans and bottles to pass since they cannot tear open all the bags. This often results in noncompostables reaching the grinders, which may affect hammer wear. The belt then passes around a magnetic pulley where cans and other ferrous metal objects are separated from the refuse. Some plants may employ a primary grinding operation prior to magnetic separation to reduce the amount of compostable material that might be trapped by the ferrous materials and removed with them. The rejected material, including that removed at the receiving building, is weighed and hauled 4.6 miles to the Johnson City landfill. About 27 percent of the incoming material was rejected during the period of this report because no salvaging was practiced.

After removal of noncompostables the refuse proceeds to either a hammermill or a rasping machine for comminution. These are so placed that they can be used alternately for comparison of efficiency and costs of operation and maintenance.

The hammermill (Figure 11) is of the swing-hammer type, having 44 chisel point hammers each weighing 21 lb. The grate bars have 1-1/2- and 2-1/2 in. openings. The mill is driven at 1,150 rpm by a 250 horsepower electric motor and has a rated capacity of 12 tons per hr.

The rasping machine (Figure 12) is similar to that developed by the Dutch N. V. Vuilafvoer Maatschappij (VAM). It was imported from the Netherlands where it was constructed by the Dorr-Oliver Company. This machine consists of a covered cylindrical housing 18 ft in diameter and 8 ft 6 in. high not including the height of the conical cover. The perforated floor is about 3 ft above the bottom of the housing. Revolving arms attached to a vertical shaft in the center scrape the refuse against projecting pins in the floor and on the wall of the housing, finally

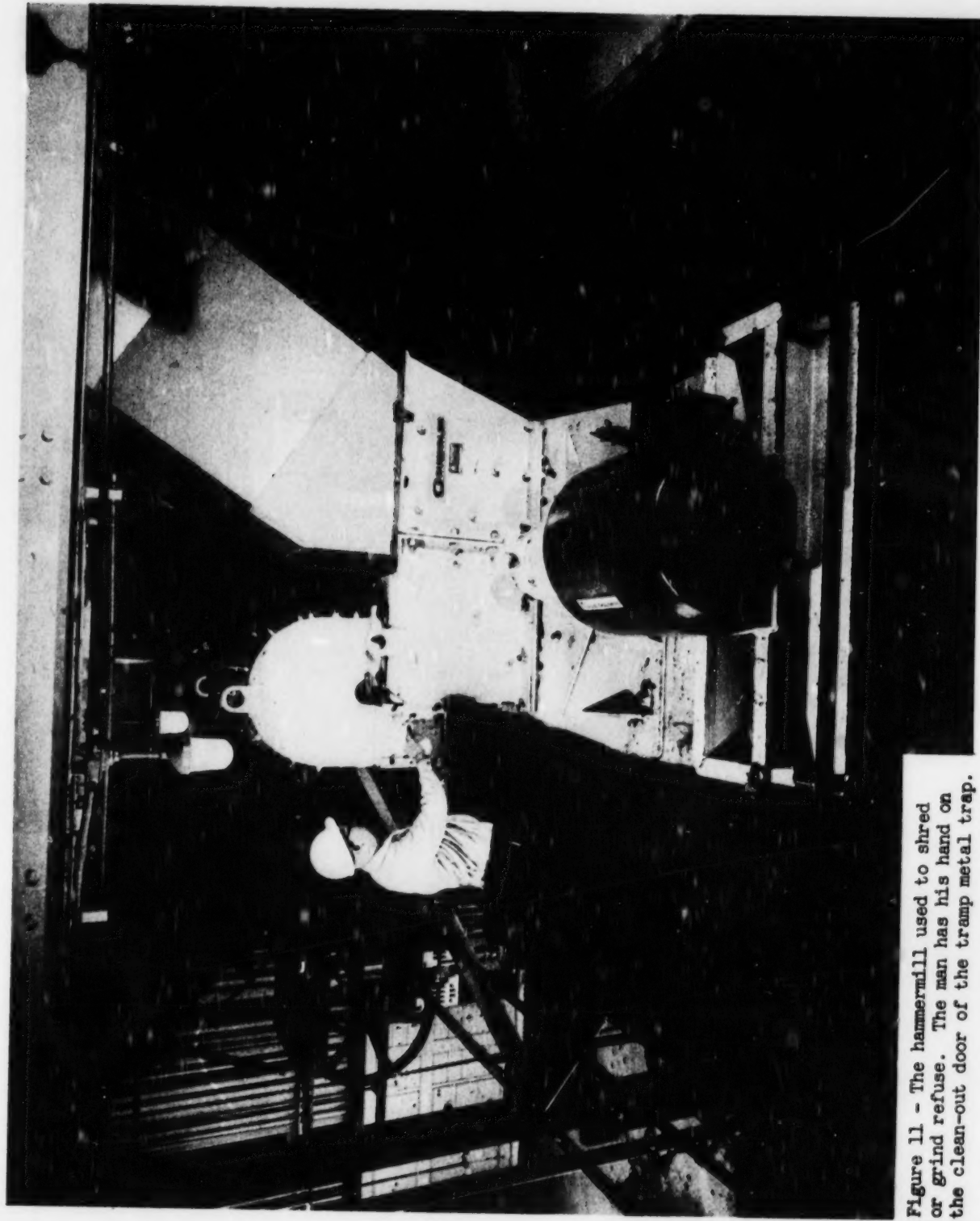


Figure 11 - The hammermill used to shred or grind refuse. The man has his hand on the clean-out door of the tramp metal trap.

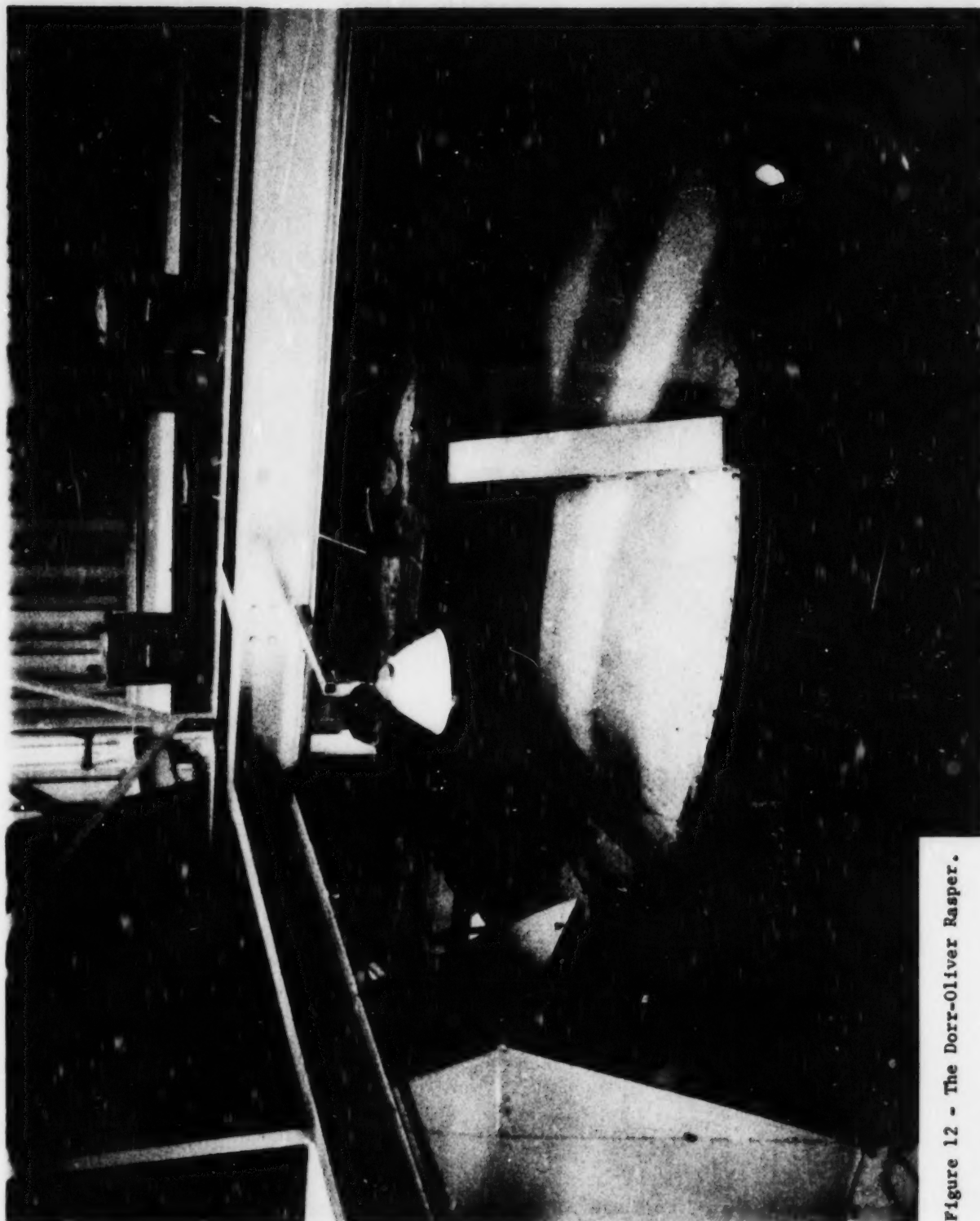


Figure 12 - The Dorr-Oliver Rasper.

forcing it through the perforations. The arms are driven by two 40 horsepower electric motors.

Refuse as received has an average moisture content of 39 percent. When using the rasper, water is added in the receiving hopper to presoften cardboard. Water is also added in the rasper. When the hammermill is used, water is added after grinding at a point ahead of the refuse-sludge mixer. The ground refuse or refuse-sludge mixture is adjusted to a moisture content of 50 to 60 percent by wet weight.

Raw or partially digested sludge containing 3 to 5 percent dry solids is pumped to the composting plant from the nearby sewage treatment plant. When using sludge from the same population generating the refuse, the water content is greater than that needed to obtain the 50 to 60 percent moisture content in the ground refuse-sludge mixture to be composted. Thus, especially with an operation using a rasper, sludge dewatering must be provided. For sanitary reasons it is impractical to add sludge to the refuse at any point in the process ahead of those places where the workmen must come into contact with the refuse.

Sludge is thickened in a Permutit Dual Cell Gravity (DCG) Solids Concentrator (Figure 13) to a moisture content of about 85 to 88 percent. This apparatus uses a revolving filter of fine-mesh nylon cloth. As a "plug" of sludge revolves inside the filter it becomes dewatered, rolls up, and is discharged. Special coagulants (polyelectrolytes) are used to condition sludge for filtering. The filtrate is returned with other liquid wastes to the sewage treatment plant where it is treated with incoming sewage. The thickened sludge is discharged to a conveyor belt which in turn discharges it to the mixer.

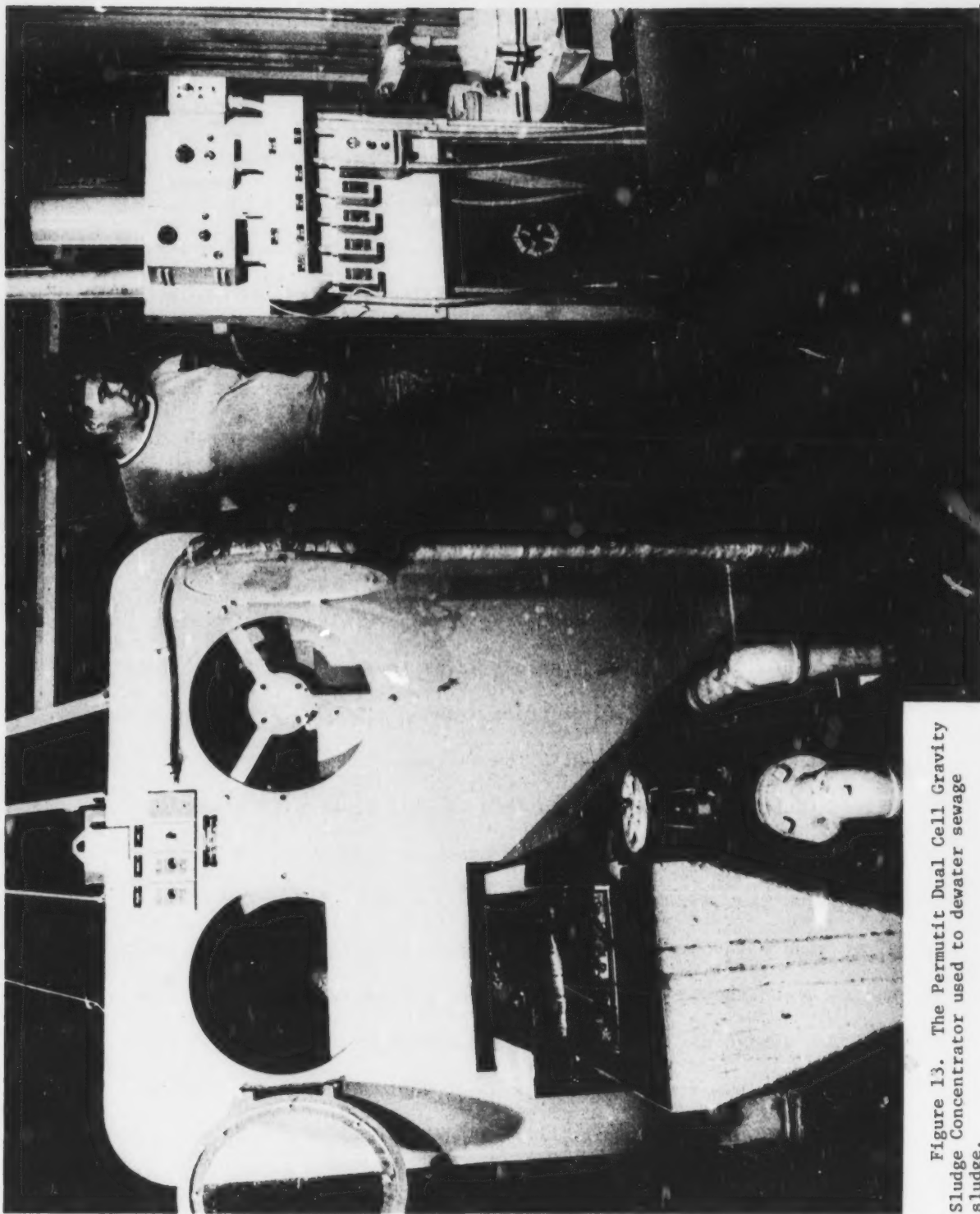


Figure 13. The Permutit Dual Cell Gravity Sludge Concentrator used to dewater sewage sludge.

Refuse and thickened sludge are mixed in a horizontal cylindrical mixing drum designed by TVA (Figure 14). As the drum revolves, internal vanes carry the mixture to the discharge end. From the mixer the material is carried to the ground refuse-sludge storage bin from which it is loaded into dump trucks and transported to the windrow area.

The ground refuse-sludge mixture is composted in windrows on a 4.8-acre area graded and stabilized with crushed rock. The windrows (Figures 9 and 15) are laid down so as to have a section as near to 9 ft wide and 4 to 4-1/2 ft high as possible. They can be as long as 230 ft. The "haystack" shaped cross-section will shed rain and the mass of a windrow so shaped will contain the heat of decomposition and can be aerated easily. The field is arranged to receive 34 windrows. As the plant operates 5 days a week and one windrow is laid down each working day, each windrow can remain on the field for a period up to 45 days. The active composting time in the field is 35 to 44 days.

During the time the material is being composted on the field it is turned 8 or more times with a special turning machine (Figure 16). This patented machine straddles a windrow, turning it with a rotating toothed drum as it proceeds from one end to the other. Turning aerates the windrows to supply the oxygen needed for aerobic decomposition. To maintain the desirable 50 to 60 percent moisture content, water can be added as needed before turning. Should rain cause the moisture content to rise above the optimum, the windrows are turned as often as necessary to dispel the excess moisture and return them to the proper wetness.

After the material has composted in the open field for a period of 6 to 7 weeks it is turned, taken from the field, and deposited in the

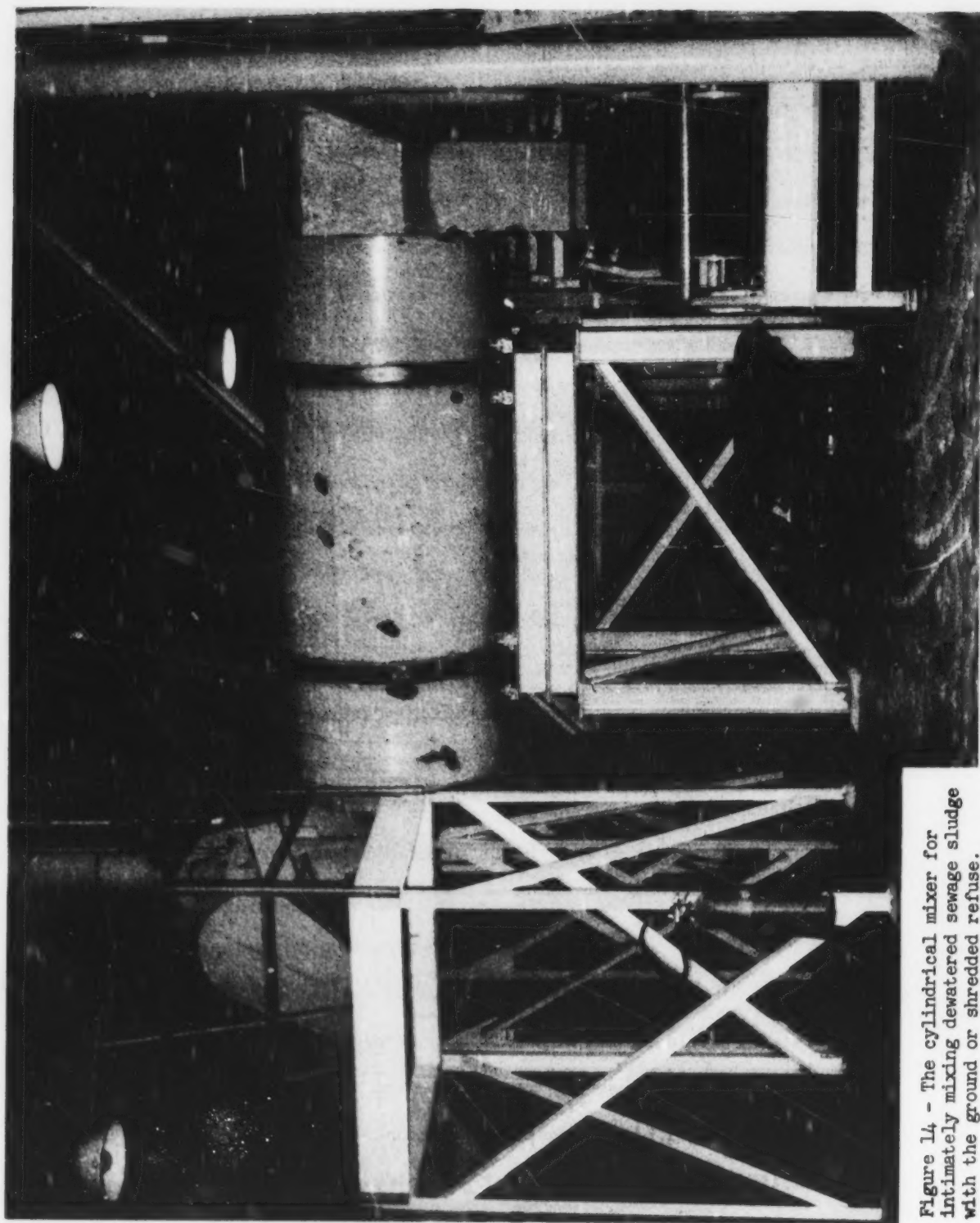


Figure 14. - The cylindrical mixer for intimately mixing dewatered sewage sludge with the ground or shredded refuse.



Figure 15 - A windrow of ground or shredded
refuse.



Figure 16. The windrow turning machine. The machine straddles the windrow, turning it with the rotating drum as it passes through the windrow.

Cobey composter, front view.

curing and drying shed (Figure 17). This shed is 60 ft by 200 ft and provides a curing and drying period of 2 weeks, which is frequently insufficient to adequately dry the compost for screening.

Following the drying period, compost is screened and reground as required using a vibrating screen and a hammermill for this purpose. The screen is equipped with interchangeable wire mesh screens of 1/4 in. and 1/2 in. openings. The mill is of the swing-hammer type using hammers weighing approximately 2 3/4 lb each. A 100 horsepower electric motor drives the mill at 3,540 rpm and the rated capacity is 10 tons per hr. The screening installation is shown in Figure 18. Compost is stored either in the unground and unscreened state or in the finished condition in stockpiles.

Construction Costs. Construction of the composting plant began on May 18, 1966, and was completed in June 1967. The total cost, including that of modifications made since startup, is \$958,375. Constructed as a plant for both demonstration and research and including some duplicate equipment for comparison, the construction cost is somewhat more than would be required for a municipal plant.

Modifications Made Since Startup. Many modifications have been made to the plant since operations began. Important ones are tabulated below for the value they may have to future plant designers.

1. Enlarging of chutes at transfer points, and enlarging of entrances to grinders, mixers, etc. was necessary to overcome jamming and clogging of raw and ground refuse.
2. Repairing and strengthening the drive of the drum mixer and setting same in level position. Modification of vanes or flights inside the mixing drums. It was found that the

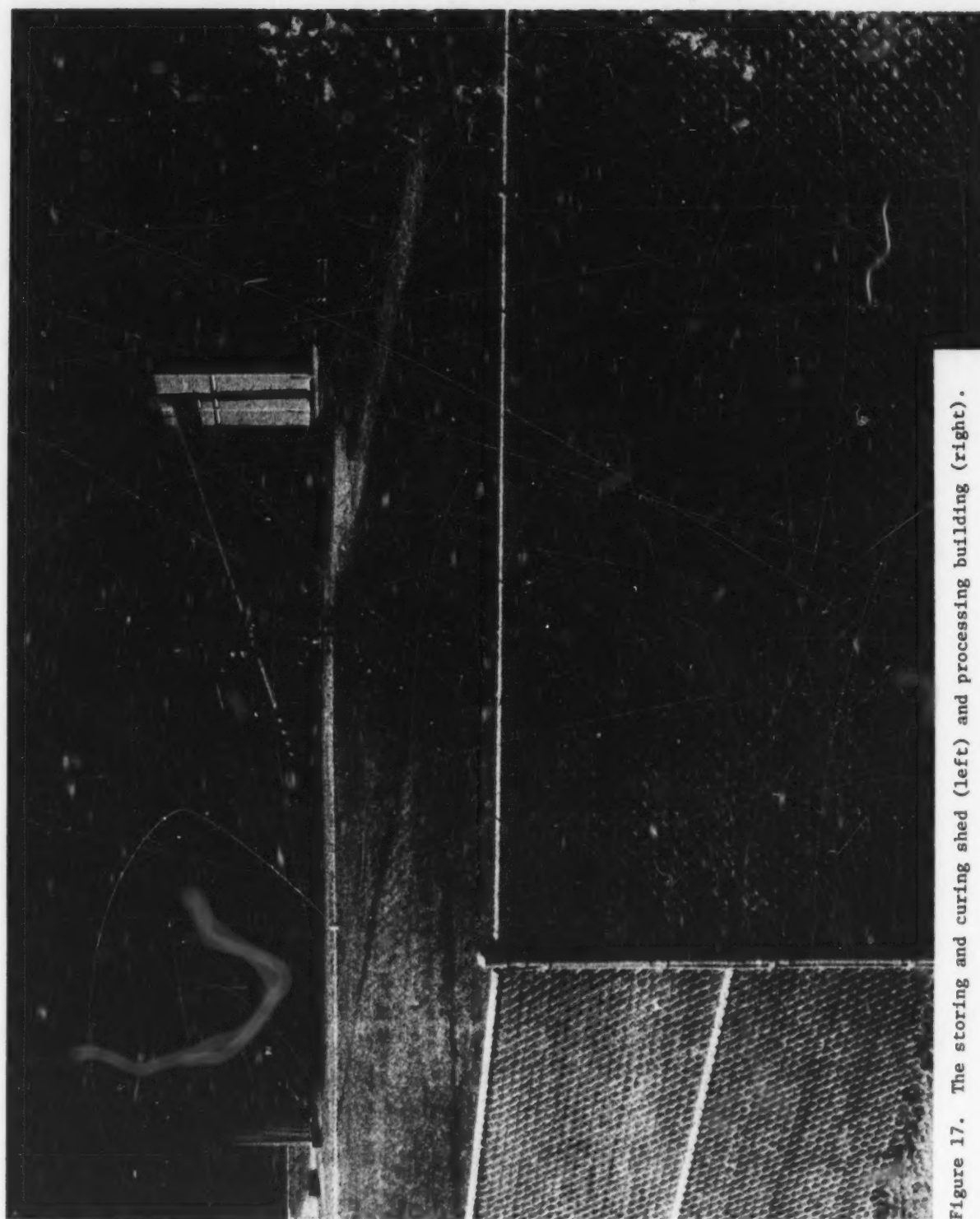


Figure 17. The storing and curing shed (left) and processing building (right).



Figure 18 - The final screening and grinding equipment. Compost is lifted by the bucket elevator and fed to the vibrating screen. Screened material is being collected in the truck. Material not passing through the screen is ground in a hammermill and recycled to the screen.

original inclination was not needed to carry the material forward. The level setting alleviated a side thrust on the supporting and rotating mechanism.

3. Addition of wipers to underside of conveyor belts and installation of drip or catch pans under the belts.

4. Addition of a curb or coaming around the floor which supports the DCG sludge filter and its appurtenances.

Spillage in this area had caused cleanup problems.

5. Laying of plywood flooring over the grating floor at the picking station to prevent spillage to lower level. This also gives more comfort to men who must stand for long periods.

6. Covering conveyor belt drive motors to protect them from dust and spillage.

7. Applying thermal tape to pipes and valves in the process building to protect them against freezing. Installing heat lamps at end pulleys of certain conveyor belts to prevent freezing of belt to pulley during shutdown.

8. Removal of cover on cross belts from grinders to mixing drum. Covers over belt are not necessary except where they traverse an open area where the wind may cause a problem.

9. Installing a vertical pipe loop in the sludge pipeline between the metering pump and the sludge-flocculant mixing tank to equalize the hydraulic head of sludge in the holding

tank. It was found that the diaphragm sludge metering pump would not operate satisfactorily with the high positive head on the suction side resulting from the elevation of the sludge holding tank.

10. Removal of strut across receiving hopper at leveling gate end thus removing a cause for jamming. There should be no structural parts which catch refuse over or alongside a hopper.

11. Modification of chute under the leveling gate. A man must be able to dislodge refuse which may jam the flow at this point.

12. Installation of dual controls for the leveling gate and the plate conveyor at a station beyond the leveling gate. This gives the man beyond the leveling gate an opportunity to shut down this machinery when necessary.

13. Erection of targets or poles for aligning and positioning windrows. Ground refuse-sludge mix is deposited by trucks and the drivers need some guide in getting windrows in the correct position.

14. Adding pads to the bucket of a payloader to give clearance between it and the stabilized rock base of the field to prevent picking up rock with compost when it is being removed or when windrows are being shaped.

15. Correcting the slippage of the elevating conveyor belt by addition of weights for tension.

16. Adding skirts to the sides of the elevating conveyor belt to prevent spillage of refuse. This has saved much cleanup time.

17. Installation of a larger discharge gate for the reject bin. This bin discharges from the bottom. Gates must be as large as possible to avoid arching above the constricted lower part.

18. Installation of a larger discharge gate for the ground refuse bin. As in Item 16, gates must provide larger openings than those needed for grain, coal, or crushed stone.

19. Installation of a 12-ton-per-hr hammermill to replace the original 7-1/2-ton-per-hr mill. This is discussed later in the section on operations.

20. Back flow preventers were installed in the processing and receiving buildings and the composting field to protect the fresh water system from backflow from the sludge dewatering, washdown operations, and other possible sources of contamination. In the case of the sludge dewatering installation, the water supply piping was redesigned and reworked to enable one back flow preventer, located in a loop of pipe above the highest level of all other lines in the complex, to protect the potable water system from back-siphonage from this operation.

Staffing. For two years, the Division of Research and Development, Bureau of Solid Waste Management, maintained at the plant site a staff

consisting of a Project Engineer, a Staff Sanitary Engineer, a Staff Chemist, a Staff Microbiologist, and a Staff Assistant. Thereafter, the technical staff was reduced to a Project Engineer and two part-time technicians. Laboratories, equipped for research and much more complete than would be needed for simple process control, were established on site for the chemist and the microbiologist.

The Office of Health and Environmental Science, TVA, is the official liaison between the TVA and the Bureau of Solid Waste Management. While this office has no resident staff at Johnson City, all interagency matters are handled through its staff. This office also maintains surveillance over the health of the TVA personnel at the plant with special attention to possible occupational problems specific to composting.

The plant is operated by the Division of Reservoir Properties, TVA, with the following on-site staff:

- 1 Foreman - in charge of daily operations.

- 1 Assistant Foreman - is in charge of the plant in the foreman's absence and also works as an operating engineer in some phases of the plant work.

- 2 Equipment Operators - these are classified as Operator B employees. One operates the windrow turner and the front-end loaders in addition to other duties. The other operates the sludge dewatering machinery and heavy equipment.

- 3 Truck Drivers - two work on the site or transport rejects to the landfill. One operates a truck equipped with spreading equipment and delivers compost to demonstration sites.

4 Compost Plant Laborers - one laborer is stationed at the leveling gate to do gross picking and to correct cloggings which occur here. Two work at the picking station. The fourth works where directed and presently performs the task of weighing incoming refuse, rejects, and outgoing compost.

If the Public Health Service staff now at the plant did not furnish this service, there would be a need for a clerk and laboratory technician, one man may perform both duties. This clerk would relieve the one laborer of weighing.

The Division of Reservoir Properties furnished higher-echelon supervision from its Morristown, Tennessee, office.

The Division of Agricultural Development, TVA, with headquarters in Muscle Shoals, Alabama, has the responsibility for the utilization and marketing studies and has one resident Agriculturist at the plant site.

Operations and Processes

Operating Schedules. At the start, the plant operated from 10:00 a.m. to 6:30 p.m. in the period of daylight saving time and 8:00 a.m. to 4:30 p.m. in the period of late fall, winter, and early spring. The warm weather schedule was adopted because of the lateness of the first delivery of refuse from the city. In colder weather, the last load of the day was held overnight to be on hand for the earlier start.

Later, changes were made in the city's delivery schedule to enable a truckload to arrive at about 8:30 a.m. each morning. Also, it was found

that the last load of the day could be held over to the next morning even in warm weather if it was stored in the hopper and sprayed with an insecticide. Since then the plant has operated from 8:00 a.m. to 4:30 p.m. each day, summer and winter.

The plant does not usually process refuse after 3:00 p.m. The remaining hours of the day are devoted to the cleanup of the receiving and processing area.

Production. As previously mentioned, the plant is designed to process 10 tons per hr or 58 to 60 tons in 6 hr, leaving the remaining 2 hr for cleanup. It has been demonstrated that with refuse of favorable characteristics, the plant can process at this rate. The average capacity, however, is about 52 tons per day in 6-1/2 hr of grinding time.

The plant has been run as a research project. Although it normally takes all of the refuse delivered by the Sanitation Department of Johnson City, and there have been very few shutdowns, the plant has not been operated to full capacity for extended periods. Efforts are being made to extend the contributing area to a nearby city. At the present time, according to the city's Planning Office, the plant processes refuse from 31,200 persons.

Table 6 shows processing data for the period January 1968 through June 1969. The plant received an average of 34 tons per day. Based on the population served of 31,200, this is 2.17 lb per capita per day for the 5-day week and 1.55 lb per capita for a 7-day week. The 10 tons of commercial waste, routinely delivered directly to the landfill, brings the total tonnage collected to 44 tons per day. This indicates

TABLE 6

PROCESSING DATA FOR JANUARY 1968 THROUGH JUNE 1969
USPHS-TVA Composting Project

1968	Refuse received (tons)	Refuse rejected (tons)	Refuse received per day (tons)		Processing days
			Average	Maximum	
Jan.	554	142	26	48	21
Feb.	587	163	28	42	21
Mar.	698	178	33	53	21
Apr.	640	174	34	53	19
May	578	168	32	46	18
June	220	57	31	58	7
July	866	220	39	51	22
Aug.	932	214	44	55	21
Sept.	427	111	36	52	12
Oct.	544	154	39	61	14
Nov.	458	130	35	59	13
Dec.	661	178	31	45	21
1969					
Jan.	623	157	33	50	19
Feb.	573	150	29	39	20
Mar.	599	148	30	43	20
Apr.	775	213	36	48	22
May	758	218	36	50	21
June	773	226	37	53	21
Total	11,266	3,001*	34		333

*27 percent of incoming refuse.

a collection of 2.81 lb per capita per day for the 5-day week and 2.00 lb per capita per day for the 7-day week. As previously mentioned, this is low compared to the national average. Street sweepings and brush are not included in this quantity. Packing house and produce wastes are sold to piggeries. Much of the industrial waste of the city is hauled privately as is some of the household waste.

Of the incoming material, 27 percent was rejected as noncompostable and disposed of in the landfill.

A seasonal variation in refuse exists, as would be expected, and Figure 19 shows these variations.

Compost yield from the 11,266 tons of refuse received was about 5,650 tons (30 percent moisture content by wet weight). All of the compost removed from the field was not weighed. Two studies of yield, on which the above is based, are discussed in a following topic.

Receiving. The receiving hopper has a capacity equivalent to two trailer loads of refuse. When the hopper is empty, the 53 and 65 cu yd compaction trailers discharge a small part of their loads into the hopper and then pull away to deposit the remainder on the paved apron in front of the receiving building. A front-end loader is used to push refuse from the apron into the hopper. This procedure allows an inspection of the refuse, an opportunity to remove large items of noncompostables or those which interfere with the movement of the material, and the breaking up of compacted refuse. This latter treatment prevents serious bridging in the hopper. When the hopper contains refuse, the whole trailer load is deposited on the apron to be fed in as needed.

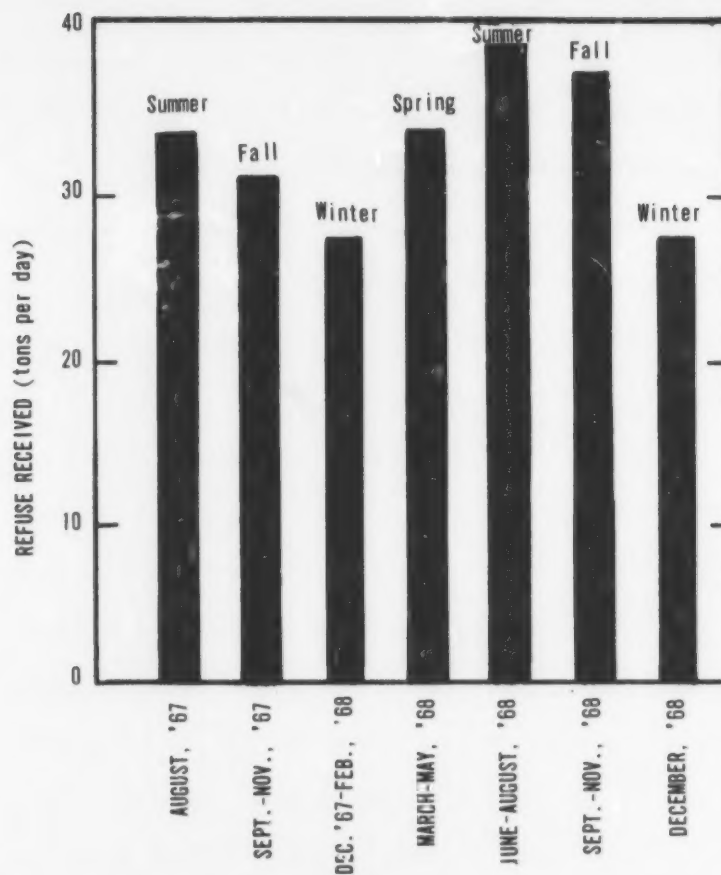


Figure 19. Quantity of refuse received at the USPHS-TVA Composting Project by seasons.

On one occasion, refuse failed to dislodge from the rear door of a 16-cu-yd packer truck as it was raised over the receiving hopper. This overbalanced the truck and the front end was lifted upward to almost a vertical position where it was caught by the eaves of the building. Both the truck's hood and the building were damaged. All packer trucks are now required to unload on the apron.

Gross picking is necessary at the receiving hopper and at the station behind the leveling gate.

Time records have been kept for the plate conveyor of the hopper and the main elevating conveyor belt. Table 7 shows that this machinery is capable of handling the design capacity of 10 tons per hr or more although the overall average for the last 6 months of 1968 was 9.3 tons per hr. On a day in which 58 tons of incoming refuse were processed, the machinery handled 9.9 tons per hr. On other days the rate of feed might be higher or lower depending on the characteristics of the refuse.

Operating difficulties since startup have been minimal. The drive motor of the plate conveyor required rewiring and a bearing has been rebuilt. Apparently the trouble was not caused by a condition of overloading with refuse. The 328 bolts which fasten the pans of the conveyor to the driving mechanism had to be replaced after some 26 months of operation. It was difficult to keep them tight and the repeated loosening ruined the threads. The new bolts have a finer thread and are installed with lock washers. An improved program of lubrication has been initiated to reduce heating of bushings, wear of bolts and other similar conditions.

TABLE 7
PERFORMANCE OF RECEIVING MACHINERY

1968	Hours of operation of receiving equip- ment and main feed belt	Tons of raw refuse moved to picking station	Tons per hour (average)
July	85	866	10
August	85	932	11
September	44	427	10
October	66	544	8
November	55	458	8
December	82	661	8
Total	417	3,888	9
June 5	6	58	10
October 30	7	61	9
November 27	6	59	10

Due to lack of stiffness the pans or segments of the leveling gate become bowed by the pressure of nonresilient items in the refuse. From time to time the clips attaching the segments to the drive chain broke and had to be rewelded. After processing about 17,000 tons of refuse during 26 months of operation, all of the pans were replaced with pans having heavier bar stiffeners.

The elevating conveyor belt has given no trouble since installation of the skirts to prevent spillage. Occasionally cardboard or other material jams under the cover but this is easily removed.

Grinding. The imported rasping machine has performed satisfactorily in the past 18 months of operation.

The manufacturer of the rasper states that it has a capacity of 7 tons by wet weight of picked raw refuse per hr. Time and tonnage records kept over a 6-month period show the rasper to be grinding an average of 5.6 tons per hr of refuse from which noncompostables and other objectionable material have been removed (Table 8).

At 6 tons per hour feed rate the rasper must run for about 10 min when refuse is first fed to it before effective grinding is accomplished. It then builds up to a maximum production which can be maintained by keeping it full. After the feed belt is stopped, the machine must continue to run at a decreasing rate of production to process the grindable refuse remaining in it. If the rasper is emptied of grindable material at any time during the day, this cycle must be repeated. This characteristic of its operation is reflected in the average tonnage per hr given above.

The character of the refuse has an effect on the rate at which it can be handled. On one day when 61 tons of incoming refuse were processed,

TABLE 8

AVERAGE PERFORMANCE OF RASPER

1968	Hours of operation	Tons of sorted raw refuse ground*	Tons per hour (average)†
July	113	646	6
August	108	718	7
September	57	317	6
October	77	390	5
November	64	327	5
December	96	482	5
Total	515	2,880	6

Rasper Performance on Days of Maximum Runs

June 5, 1968	6	43	7
October 30, 1968	8	44	6
November 27, 1968	6	43	7

One Hour Test Runs with Rasper Full

January 15, 1969	1	7
January 17, 1969	1	7

*Tons of sorted raw refuse averaging 39 percent moisture by wet weight, or the weight of incoming refuse minus that of rejected material. Actual weight of ground refuse produced is greater than this due to water added to obtain a 60 percent moisture content.

†The rasper must be run for about 10 minutes as refuse is fed into it before it produces a ground material. It then builds up to a maximum production which is maintained if the rasper is kept full. After the feed belt is stopped, the rasper must be run for 20 to 25 minutes to finish processing the grindable material still in the machine. Due to the schedule of refuse deliveries or for other reasons the rasper usually cannot be kept full throughout the day and the average production figures reflect this situation. The character of the refuse can also affect the production of the rasper considerably.

the 44 tons of sorted (picked) refuse were ground at a rate of 5.3 tons per hr. On another day, when 59 tons of refuse were processed, the rasper's rate for the 44 tons of picked material was 6.9 tons per hr.

On test runs of one hr with the rasper full, a rate of 7.1 tons per hr of sorted material received with a moisture content of about 39 percent was observed. It appears that this machine can meet the manufacturer's claims.

Water must be added during processing to obtain a moisture content of 60 percent by wet weight in the material laid down on the field for composting. In practice it is added first in the receiving hopper to soften cardboard and again in the rasper as needed. The rasper is equipped with spray nozzles for this purpose and will not grind dry cardboard without operating difficulties. The actual weight of material entering the rasper is, therefore, greater than its weight when received at the plant. On the occasion of the rasper's grinding 7.11 tons per hr (39 percent moisture), it was discharging 10.8 tons of ground refuse with a water content of 60 percent.

At the end of the day, there always remains in the rasper some residue. This includes material such as metal cans, items of nonferrous metal, rags, bits of wood, and wire. This material must be removed at intervals either manually or through the rejection opening.

When the refuse is difficult to grind, the rasper can become overloaded by the buildup of material. To date this has not caused any mechanical trouble but it does consume time when it is necessary to remove the excess material by hand.

Very little maintenance has been necessary. Not long after startup a bearing in one of the American-built motors required repair which was done by the manufacturer. The main bearing of the shaft which carries the rotating arms became overheated soon after operations were begun. This was corrected by a modification of the lubrication of this part.

In March 1969, after 20 months of operation and the grinding of 8,720 tons of sorted refuse, the rasper bottom plates, pin plates, and wear plates were removed and replaced. The 8,720 tons of picked refuse represent nearly 12,000 tons of incoming refuse. In September 1969, after 26 months of operation, two of the rasping arms broke at the point where they are fastened to the rotor. These were rewelded with some steel reinforcement by plant personnel. Three others, not broken, were also strengthened and such trouble is not expected to recur within 2 years.

The hammermill originally installed in the process building did not produce the particle size desired or achieve the specified capacity for grinding 7-1/2 tons per hr of raw refuse. Tests during the first 6 months of plant operation showed a capacity of 5.6 tons per hr. In late 1967 and early 1968, experiments were conducted with several grate size combinations to see if a better particle size could be obtained. The smaller the particle size produced, the greater were the operating difficulties and the smaller the grinding capacity. In March 1968, tests with the original grates showed a production of only 4.2 tons per hr.

On every occasion of operating the mill for grinding refuse, stoppages in the feed chute occurred. Before an arrangement was made whereby the

mill could continue to run after the feed belt was stopped, the mill jammed and could not be restarted until it had been opened and cleaned out. After March 8, 1968, the use of the hammermill for grinding of refuse was discontinued.

From March through December 1968, the hammermill was used only for regrounding compost for use by the TVA agriculturist. Between March and October 1968, a total of 624 tons of compost at least 6 weeks old was ground at an average rate of 8.9 tons per hr. The range of production was from 3.7 tons per hr to 15.6 tons per hr. The dryness and other characteristics of the material and the speed with which it can be fed into the mill affect the rate of grinding. Compost with a water content over 30 percent by wet weight can give trouble by sticking and jamming. Material that is very dry can create a dust problem.

In mid-October 1968, the hammers were replaced with a set which had been refaced by a buildup of welding rod. A total of 288 tons of compost was subsequently reground at the rate of 13.6 tons per hr.

The hammers taken out of the mill in October 1968 had been installed in November 1967, and had been used for 102 hr. Of this time, 27.4 hr had been for grinding refuse. Total weight of refuse for this period of grinding refuse was not determined as it was the accumulation of several short experimental runs.

Experience had shown that the hammers of this mill required refacing after 40 hr of refuse grinding. After about 27 hr of grinding, they would have had 13 hr of remaining usefulness for this purpose. Thus, 13 hr for refuse grinding were good for about 74 hr of compost grinding. At this rate, a set of refaced hammers might serve for nearly 230 hr of

compost grinding. This mill had ten 50-lb and four 15-lb hammers operating at 1,800 rpm, driven by a 125 horsepower motor. The grates were of the bar type. The mill recently installed for regrinding compost is a different type, having narrow hammers weighing about 2-3/4 lb each, designed to rotate at 3,450 rpm, and powered by a 100-horsepower motor. It is intended for grinding compost that has been rejected by the vibrating screen. Information obtained on the wearing of hammers on the larger mill is not applicable to the new final grinder.

In February 1969, a new and much larger hammermill for refuse grinding was installed. This mill is described in Table 5. During the month of March 1969, it had been operated for 47-1/2 hr, grinding 275 tons of refuse, when the hammers were taken out for rebuilding. The hammers were badly worn resulting in less efficient particle size reduction and indicating that removal after approximately 40 hr of operation seems to be necessary. Rebuilding after 30 hr will result in less difficulty in refacing.

The short experience with the new hammermill has shown that the pickers and the magnetic separator may miss large pieces of metal that will give trouble. In one case, a steel ball bearing almost 3 in. in diameter got into the mill. In another case, a large piece of metal was thrown about in the mill with such force that the 1/2-in. steel cover was bent. A tramp metal trap, which is quite heavy, was installed. This in turn necessitated the installation of a trolley hoist above the hammermill to assist in removing the trap and cover during hammer changes or for other reasons.

Experience to date has been insufficient to evaluate the cost of operating the new hammermill.

Addition of Sewage Sludge. On January 2, 1968, the routine addition of sludge was attempted.

Sludge is pumped from the primary sewage treatment plant adjacent to the composting plant into a 2,600-gallon holding tank. From this tank it is transferred to a mixing tank by a diaphragm metering pump. A polyelectrolyte flocculant is introduced into the line ahead of the mixing tank by a positive displacement feed pump. After mixing, the sludge flows into the filter.

In January and February of 1968, subfreezing temperatures on eight occasions made it impossible to process sludge. The processing building was unheated and the freezing of pipelines and even dewatered sludge was experienced. Wrapping of pipelines with thermal tape and the installation of space heat in the building have corrected this problem.

When a breakdown of the sludge filter occurred, there was difficulty in disposing of unneeded sludge due to the arrangement of the sludge return lines. It was decided to add sludge on a 3-day-a-week basis in order to carry on the essential pathogen survival studies.

In July 1968, the plant again attempted to process sludge daily. Of the 103 days on which refuse was processed in the second half of 1968, dewatered sludge was incorporated into ground refuse on 75 days.

Of about 348,000 gallons of sludge received from the Johnson City sewage treatment plant, 261,000 gallons were processed through the filter. The average number of gallons processed per day of filter operation was 3,480. On 13 days the plant was unable to process sludge because of

downtime on the filter. Of the 75 sludge processing days, the filter was operated only part of a day on 12 occasions on account of downtime. Over the 6-month period the added sludge solids averaged about 3.9 percent of the dry weight of the raw refuse-sludge mix laid down in windrows. On occasion, greater amounts were added for specific experimental windrows.

The DCG filter is capable of dewatering sludge from a water content of 96.9 percent to 85.0 percent of wet weight. The capacity (not necessarily raw sludge) is specified as 1,200 gallons per hr. The monthly average rate has ranged from 861 to 1,060 gallons per hr. The maximum amount of sludge processed on any one day has been 5,643 gallons. The equipment installed is not capable of handling all of the sludge generated by the 27,000 population served by the city sewer system.

The flash mixing tank, where the sludge is mixed with a flocculant before it enters the dewatering cells, is equipped with a DC motor, the speed of which is controlled by a rheostat. This rheostat burned out and the mixer was subsequently operated with an AC motor. This operation must be intermittent, however, because the motor runs at too high a speed. Permutit's attempts at obtaining a replacement rheostat have failed as the company that manufactures the speed control unit will not sell parts for it. An alternate solution is to install a gear reducer for the AC motor. Permutit is to supply parts numbers for such a reducer.

The sludge inlet piping to the dewatering cells splits the flow from a flash mixing tank into four parts by using a weir box. Rags and other large materials tend to clog this box, requiring continual attention to insure steady flow. The cause of this trouble lies partly in design,

which Permutit intends to correct in future models, and partly in the fact that the Johnson City sewage treatment plant does not have comminution.

Trouble was experienced with the displacement of the sprocket idlers over the cells. When these came loose, the cell moved out of position and became deformed and jammed. The manufacturer recognizes this fault and will design a correction into a test machine being constructed; it is not known if this correction can be applied to the apparatus installed in the composting plant.

The nylon mesh filter medium is stretched between rubber seals which in turn are attached to a drive chain which imparts the rotary motion to the cells. The seals were not strong enough to stand the stress of being part of the drive mechanism and still support the weight of the sludge roll between them.

Metal inserts in the seals to which the drive chains are bolted proved to be too weak for the purpose. The machine was developed for dewatering digested sludge which forms a smaller roll than the raw sludge treated at the composting project. Raw sludge forms rolls in the order of two to three times the size of those for digested sludge, overloading the seals, and pulling out the inserts. Each time this happened the seal had to be replaced before the operation could be continued, a rather time consuming task.

Due to these troubles, the processing of sludge in the first half of 1969 was intermittent.

Permutit has redesigned the seals so that the new inserts have two horizontal projections instead of one, the web is incorporated into the

new seal as it is poured instead of being glued on later, and the new seal is poured in one piece instead of several short pieces. The result is a unit construction which should be capable of carrying a much larger load than the original seals. The manufacturer supplied the project with a full set of these new seals in the late spring of 1969, and one unit of the filter was equipped with them. In July 1969, it was decided to temporarily cease the processing of sludge in order to devote time and funds to other investigations. The new seals have therefore not been tried in continuous operation.

From the above discussion, it can be seen that the sludge operation has fallen below expectations. In defense of the filter, which was still in the developmental stage, there were times when other operations in the plant or difficulties at the sewage treatment plant resulted in a short day's run. There were times when the quality of the sludge as received made it unmanageable and part of it had to be wasted back to the sewage treatment plant. As it is sometimes drawn from the digester and at other times directly from the primary settling basin, the quality of the sludge has been variable. Furthermore, since there is no comminutor at the sewage treatment plant, rags, sticks, etc., may come through and clog the troughs in the DCG. Raw sludge has better dewatering characteristics than digested sludge.

Handling and Storage. The ground refuse-sludge mixture is moved by conveyor from the mixer to a bucket elevator which lifts the material into a 12-ft diameter cylindrical storage bin. The bin was designed to hold several truckloads of material so that a truck could shuttle back and forth

from this point to the windrow field. The bin discharged to the truck through a horizontal sliding gate in the bottom. The bottom third of the bin tapers toward this opening.

It was found that due to arching ground refuse would not flow through the gate after it builds up in the bin. A vertical screw feed was tried, but was unsuccessful. The gate has been enlarged and now a truck can load, make a short trip, and return to be loaded again without trouble. If the truck does not return shortly, however, the bin will clog. The conclusion is that bins should have straight sides and a live floor. A common ensilage wagon with such a conveyor floor has been tried with success in an experiment.

Windrow Maintenance. Although the windrow turning machine successfully mixes and aerates the composting refuse, structural and mechanical troubles have caused it to have considerable downtime, this being only the second such machine ever built by the manufacturer.

The machine as delivered tended to spread the windrows. The addition of teeth to the rotor and changes in their inclination to the center improved the capability to maintain the shape of a windrow. A vexing trouble was the frequent breaking of the drive chain. Overheating of fluid in the hydraulic transmission resulted in failure to transmit sufficient power.

In the spring of 1968, the manufacturer had a mechanical engineer design some improvements and sent a mechanic to the plant to make modifications. Work on the rotor teeth resulted in a machine capable of shaping windrows newly laid down by the dump trucks. A stronger drive chain with an improved idler sprocket arrangement was installed. The hydraulic drive

system was improved including cooling of the fluid, some repairs were made to the rotor, and the chassis or frame was somewhat strengthened.

In August 1968, a shaft in the gear train broke on two occasions. Since the motor produces over 100 horsepower (BHP 122 by specification) and the reducing gear has a nameplate rating of 18 horsepower, TVA operations staff installed a torque limiter to protect the gear train.

Despite the torque limiter, gear train troubles have persisted. Some motor troubles were experienced but these had nothing to do with the design of the turner.

In December, the axle and king pin of one of the rear (steering) wheels broke. This was expected due to the light construction and the stress put upon it by an unsophisticated steering arrangement. The steering has been improved by the TVA and the stronger king pins installed.

After the modifications made by the manufacturer in April 1968, the machine moves over the ground at 0.27 miles per hr instead of the 4 miles per hr claimed by the manufacturer. This speed is not appreciably changed in working through a windrow and the machine appears to be able to aerate about 500 tons of compost per hr. Even at this slow rate, it is capable of turning the 34 windrows in 4 to 5 hr. Rarely would it be necessary to turn all windrows on the same day.

During composting, the windrows tend to slump. To maintain a desired windrow cross-section, they must be reshaped. Before turning, the margin or foot, where the side of the row meets the ground, must be picked up and placed on top or at the end of the windrow to assure that this part of the material will be subjected to the heat generated within the central mass.

Windrows must be kept at 50 to 60 percent moisture content at least until the 28th day. If they become too dry, they must be wetted and turned. Should they become too wet, turning can help to dry them. In the summer of 1967, wet weather gave some trouble. The summer and fall of 1968, were much drier than were these seasons in 1967. Added to this, Johnson City suffered a severe water shortage and asked users to practice conservation as far as possible. The watering of windrows was cut to a minimum and by the end of September, the use of domestic water for the complete daily washdown of the plant was discontinued. Portable irrigation pipe and a portable pump were brought in from a nearby TVA installation. The pump was set up near the plant on the bank of a creek entering the Watauga River and this supply was used for washing down operations. The city put a new filtration plant into operation in mid-1969 and there is now an ample supply of water.

Curing and Drying. As mentioned above, the water content of the digesting refuse is kept between 50 to 60 percent by wet weight throughout the first 28 days. By the 42nd day, the moisture content is usually between 40 and 50 percent. Trouble has been experienced in air drying this compost to the 25 to 35 percent moisture content desired for screening, regrinding, and final disposition. Except in very dry weather, the 2-week storage under cover of the curing shed does not accomplish this moisture reduction. In wet weather, the moisture content can be static for long periods. In dry weather, better results have been obtained by leaving windrows uncovered on the field exposed to the sunlight. Experience indicates that for commercial production of compost in a climate

similar to that at Johnson City, mechanical drying equipment may be desirable.

Screening and Grinding. In the summer of 1968, regrinding was done in the hammermill originally installed for grinding raw refuse. No screening was done. In February 1969, a mill procured for regrinding and the vibrating screen were installed. The winter had been wet and extreme difficulty was experienced in obtaining material dry enough to screen or regrind. It was not until late April that compost was dry enough for real testing. None had reached the favorable moisture content of 25 percent.

The use of compost in agriculture is seasonal, in fall and spring. It appears that compost will have to be screened and reground in late summer and stockpiled for fall and spring use.

The compost as taken from the field is still quite hot but has been reduced to an innocuous, earth-like material with no objectionable odor. The composting activity still goes on but at a slower rate. The heat is dissipated slowly from the inner mass of stockpiles, but is reduced. Drying reduces microbial activity and further enhances cooling. Decomposition is not complete, but for many uses, it has reached a practical point in large-scale composting.

Although the vibrating screen and a compost regrinding mill were installed in February 1969, operating troubles and drying difficulties have prevented a full evaluation of this phase of the operations.

The compost is first screened and that material which does not pass through the screen is ground and then recycled to the screen. Considerable trouble was experienced due to blinding with the 1/4 in. and 1/2 in. woven

wire mesh screens first installed. A perforated plate screen with 7/16-in. openings is now being used. This screen will pass about 50 percent of fresh compost when the moisture content is between 30 and 35 percent by weight. Production is 1 to 3 tons per hr, much less than the 10 tons per hr expected.

The hammermill installed for grinding compost has proven inadequate and has experienced excessive hammer wear. A set of hammers furnished with the mill lasted for only 8 hours grinding at the rate of about 2 tons per hr. Because of the excessive cost of replacing or rebuilding the hammers furnished with the mill, hammers fabricated from strap steel are now used and discarded when worn. About 80 tons are ground between changes.

Because of the disappointing performance of the small hammermill, consideration has been given to replacing it with the Williams hammermill formerly used for grinding refuse. This mill has shown a capability of grinding more than 10 tons per hr of compost. A rotary, drum-type screen is being considered to replace or supplement the vibrating screen.

Fly Control. On June 20, 1967, it became evident that flies were a problem.

Through the Regional SWP Chief, Region IV, an inspection by an entomologist of the National Communicable Disease Center was arranged. The Division of Health and Safety, TVA, also arranged for a TVA entomologist to visit the plant. It was the opinion of these two entomologists that although flies were breeding on the windrow field, the greater number had come to the plant in the refuse as eggs, larvae, and pupae. In the several days that it takes for a windrow to reach an elevated temperature, eggs

hatch, and larvae migrate to suitable places for pupation. After windrows heated up and were turned twice a week during the first 14 days, breeding was lessened because of the heat destruction of eggs and what breeding appeared occurred mostly at the "toe" where turning is less efficient and temperature is low.

Before the inspections by the entomologists, the receiving and process buildings had been sprayed with a pyrethrum-piperonyl butoxide space spray and Dibrom in solution had been used on the walls and on the windrows. Application was by a gasoline powered sprayer. Only partial control was obtained.

The CDC entomologist recommended Dimethoate in an emulsifiable concentrate for space spraying and as a mist or fog in the windrow area to kill adults. For larvae, Dimethoate wettable powder suspension was recommended for a residual on the walls of the receiving and processing buildings. At the receiving building, larvae could be seen migrating from fresh refuse. He further recommended that Dimethoate wettable powder be incorporated into the ground refuse before it was laid down in windrows. This material was obtained and tried as a residual and a mist. The equipment on hand did not create a mist of the magnitude necessary and a spray was applied directly to the windrows. Some abatement was accomplished but flies continued to be a problem until cold weather set in. The recommendation for adding the insecticide to the ground refuse was not followed because of the unknown effects upon the flora carrying on the composting and upon the pathogen survival study.

The inspecting entomologists pointed out the fact that the once-weekly collection in Johnson City was related to the large number of larvae in

every stage of development found in the incoming refuse. In their opinion, two collections a week would probably aid in the control of flies at the plant.

The first significant fly population of the summer of 1968 was observed at the plant on July 5. Using a Dynafog Model 40 gph nonthermal fogger or mister and an emulsion of 12 gallons of 23.4 percent Dimethoate emulsifiable concentrate in 38 gallons of water, control was effected. This dosage is equal to the recommended 6 gallons of 50 percent Dimethoate EC in 50 gallons of water. The speed of application was 4 miles per hr and it was found that only the four youngest windrows on the field needed fogging. The dosage was later reduced to 8 gallons of concentrate in 42 gallons of water with equal control being accomplished.

The receiving building and the apron were sprayed with a Dimethoate emulsion for the residual effect. Although fly larvae could be seen migrating from fresh refuse received at the plant, very few appeared to pupate. On the composting field, there was some breeding of flies in the toe of the windrows. This material is now picked up with a payloader and placed on the top of a windrow or at the end before each turning.

Interviews with county agriculturists and health officials disclosed that fly populations had been abnormally high on the refuse dumps in nearby Elizabethton and Jonesboro and in dairy barns in the summer of 1967, in contrast to abnormally low populations in the summer of 1968. The rainfall for the area in the period July through September in 1967, was 11.14 in. (normal being 11.97 in.) with 19 consecutive days of rain in July. In 1968, the precipitation for the area was 6.14 in. with a

comparatively dry July. The experience of 1968, therefore, did not show to what extent the controls practiced would have been effective in 1967.

In the period July through September in 1969, the rainfall in the area was 14.60 in., as compared to the normal of 11.97 with 8.18 in. in July mostly occurring as thundershowers followed by sunlight. At the plant, where a rain gauge was being maintained, the rainfall was 9.65 in., with the July precipitation well below that for the area. At no time during that summer did flies become a problem, indicating that the control measures described above appear efficient.

Removal of Plastics and Glass. Plastics, particularly plastic film, present a problem. Shreds of plastic film persist through composting and are carried from the windrows by the wind, causing an unsightly appearance of the grounds. Regrinding and screening reduce the size and amount of the shreds to where they are unobjectionable in the finished product.

As it would be advantageous to remove plastic film before the refuse-sludge mix goes onto the field, TVA has conducted experiments for film removal. Several arrangements of apparatus have been tried, using the principle of separating the plastic film from the ground refuse solely by air currents. Although these showed promise, a significant amount of film has not been removed in this way.

Glass particles are objectionable if they are not ground fine enough or if sharp pieces remain after grinding. At Johnson City, when a rasper is used, glass is not reduced to fine particles as it is in the two or more stages of hammermill grinding used in most other plants.

Trials of a drum-type ballistic separator did not show sufficient removal of glass. This apparatus consisted of a revolving drum on which

the ground refuse falls, the glass and other dense materials being bounced off with a trajectory different from that of the lighter organic materials.

TVA also unsuccessfully experimented with an apparatus consisting of a rotating cone on a vertical axis, mounted inside a cylindrical tank. The theory of operating this apparatus was that the refuse falling on the cone, which had an apex angle of about 152 degrees, would be slung off. An attempt would then be made to collect the glass and other dense particles which bounced off the wall of the tank at a trajectory different from that of the organic material. Beneath the cone, suction was to be used to remove plastic film loosened from the stream of refuse by the motion imparted by the cone.

PROJECT STUDIES AND INVESTIGATIONS

Composting Process Studies

Temperature Studies. In the first year of operation a considerable body of information was accumulated on temperatures attained in the composting refuse. Readings were taken with a portable single probe thermistor type telethermometer. Figures 20, 21, 22, 23, and 24 show the results of observations on 152 windrows at the 1-1/2-ft depth over the period June 20, 1967 to June 14, 1968. Temperatures over 140 F were recorded in all series for a number of composting days. For the series of windrows 1 C through 34 C, which spanned a period of very cold weather in January and February 1968, a shorter period of high temperatures was observed than for the other series of observations.

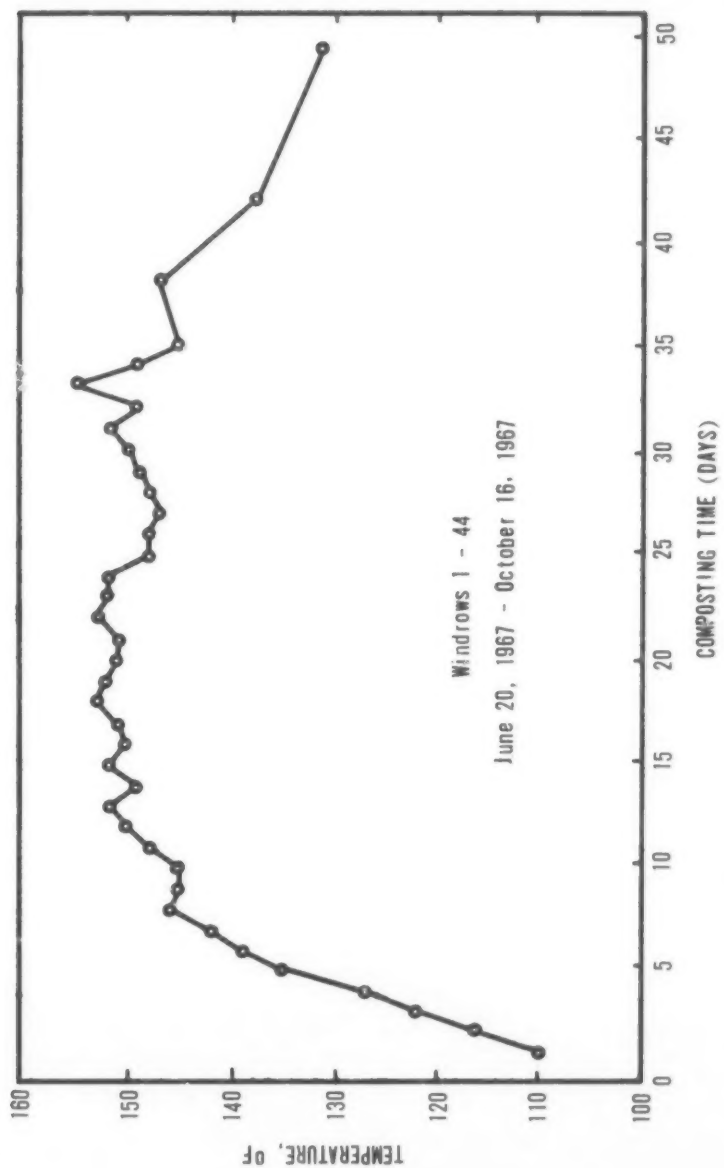


Figure 20. Average temperatures at the 1-1/2-ft depth in windrows 1 thru 44.

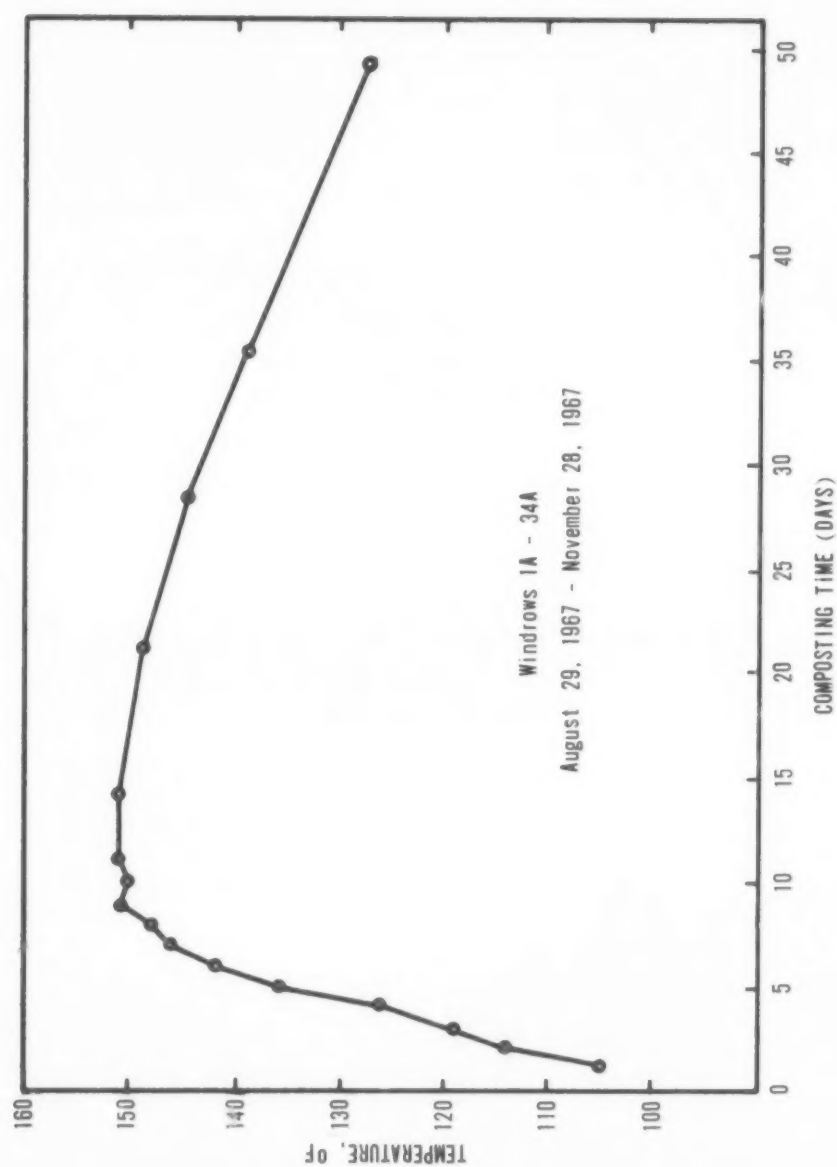


Figure 21. Average temperatures at the 1-1/2-ft depth in windrows 1A thru 34A.

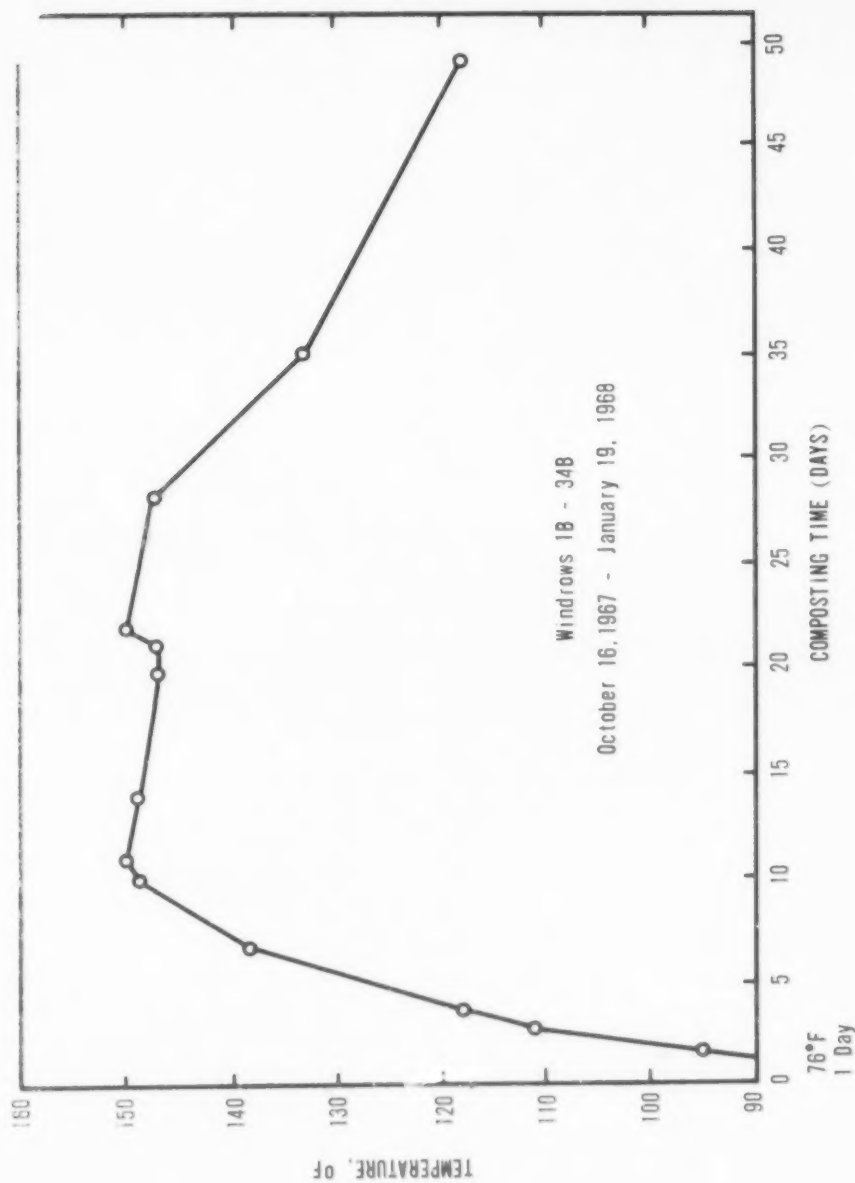


Figure 22. Average temperatures at the 1-1/2-ft depth in windrows 1B thru 34B.

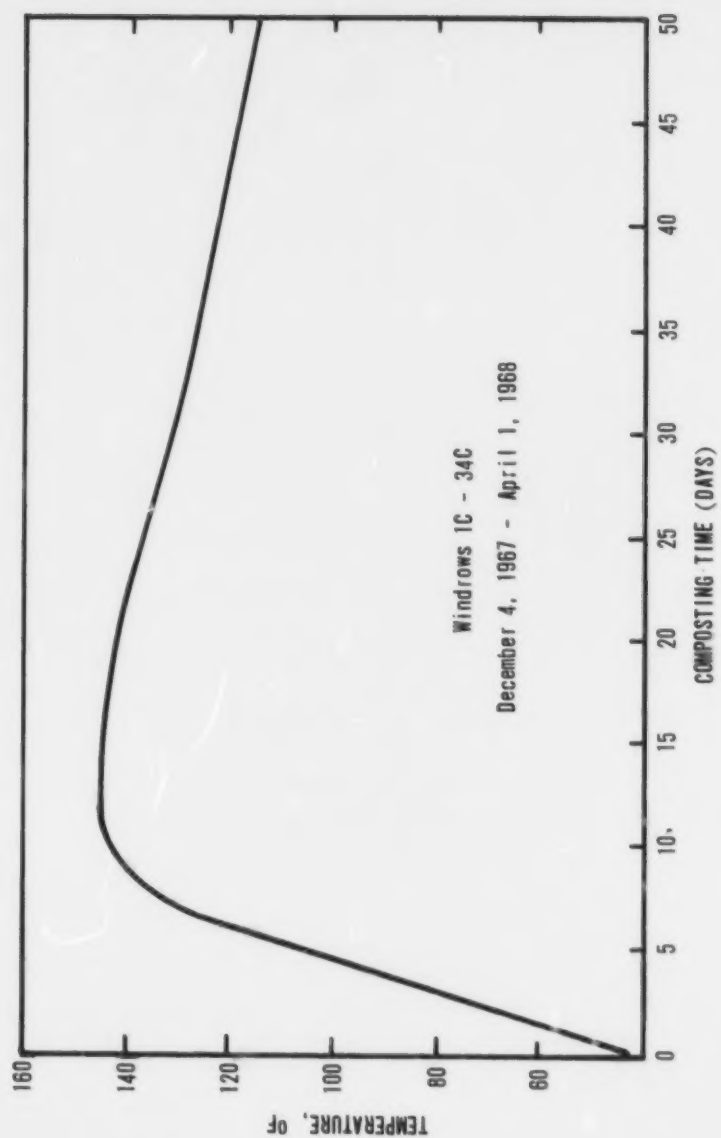


Figure 23. Average temperatures at the 1-1/2-ft depth in windrows 1C thru 34C.

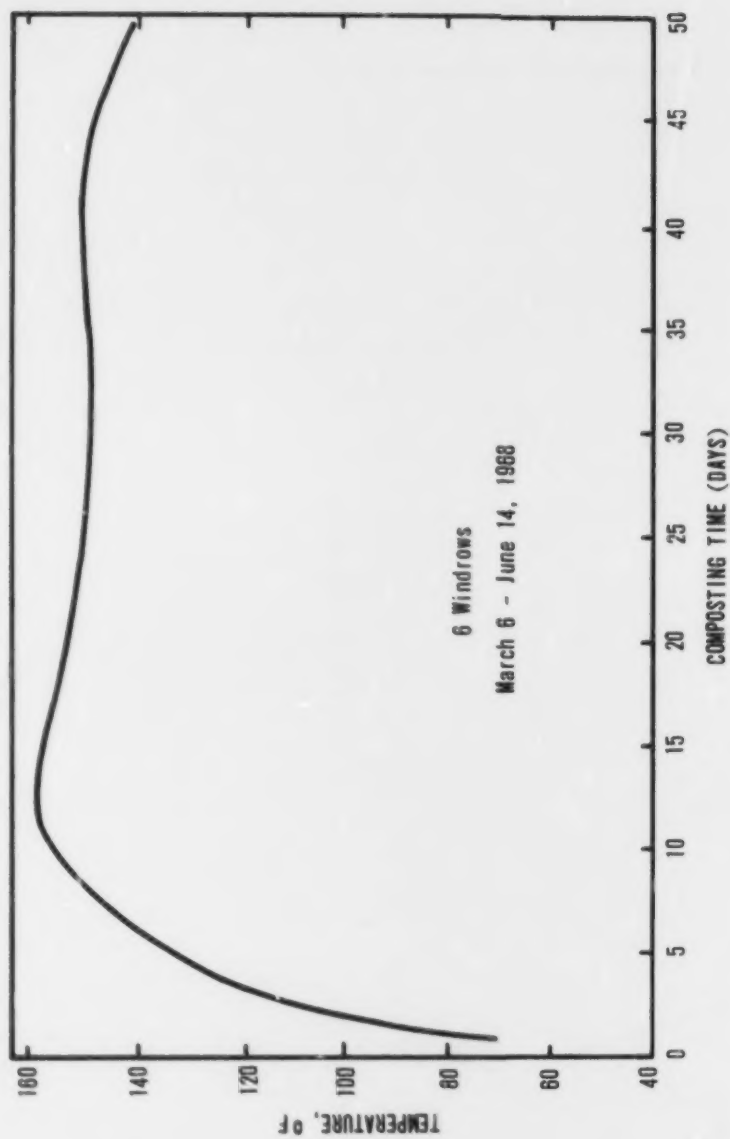


Figure 24. Average temperatures at the 1-1/2-ft depth of six selected windrows.

In the period April 26 through June 26, 1968, continuous temperature observations in a windrow were made with a YSI 12-point thermistor temperature recorder. The recorder monitored each point for 5 min--10 points within the windrow, one point for the ambient temperature, and a point for a register mark. The instrument cycled the 12 channels once every hr, recording about 11,000 points for the 42-day composting period. Temperatures were recorded at depths of 5, 13, 23, 32, and 41 in. at two stations 10 ft apart. The windrow height was 45 in.

The first 11 days of observations at Station 1 at various depths are shown in Figure 25. Station 2 showed a similar pattern of data. In this period the windrow was turned just before inserting the thermistor probes and again on the 4th, 7th, and 11th day. Immediately after a turning the windrow has a uniform temperature, after which the various depths reach different temperatures. This results in three groups of data over the period illustrated. Figures 26 and 27 show the temperatures recorded during the period 22 to 28 days for several depths for the two stations. Figure 28 shows the curve for the 22- and 32-in. depths at Station 1 over 42 days. Station 2 exhibited a similar pattern. Breaks in the curve show points of turnings. Interior temperatures change rapidly during the first 2 weeks of composting after which the interior temperatures show no great fluctuations. Surface temperatures, however, vary considerably during the entire composting period, depending upon season and weather conditions.

In the period November 4 through December 30, 1968, temperatures were continuously recorded for another windrow at two stations. Figure 29

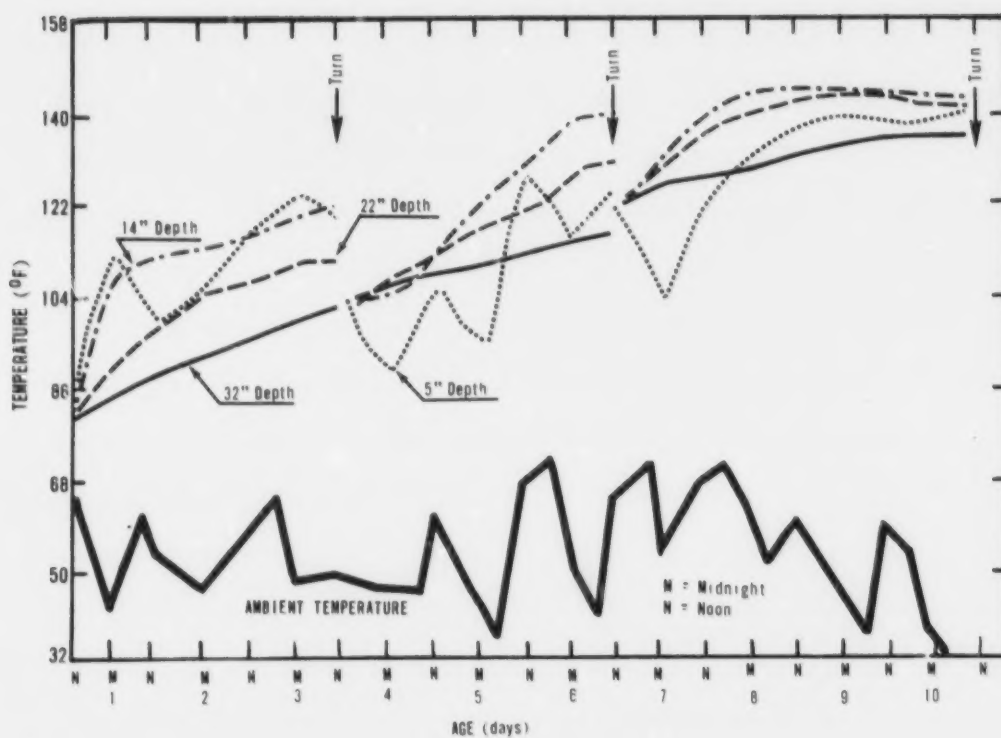


Figure 25. Temperature profiles of a selected windrow during the first 11 days of composting.

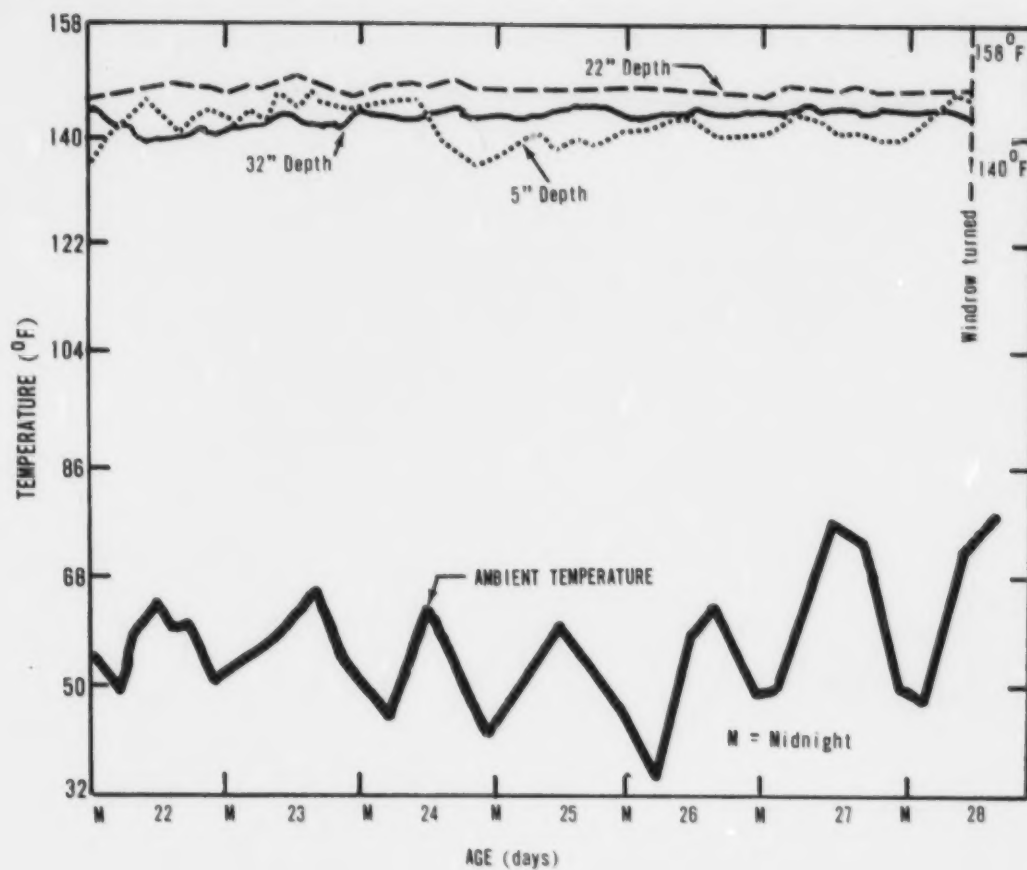


Figure 26. Continuous temperature record of windrow 17E, 22nd to 28th day (Station 1).

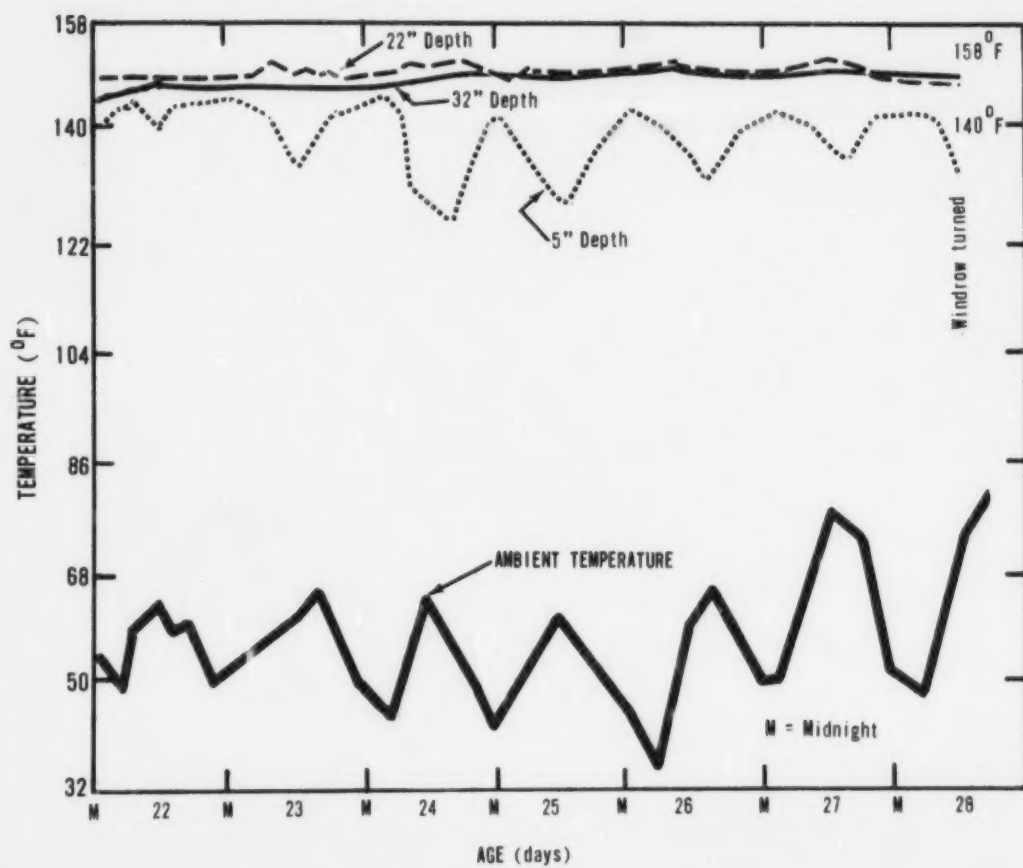


Figure 27. Continuous temperature record of windrow 17E, 22nd to 28th day (Station 2).

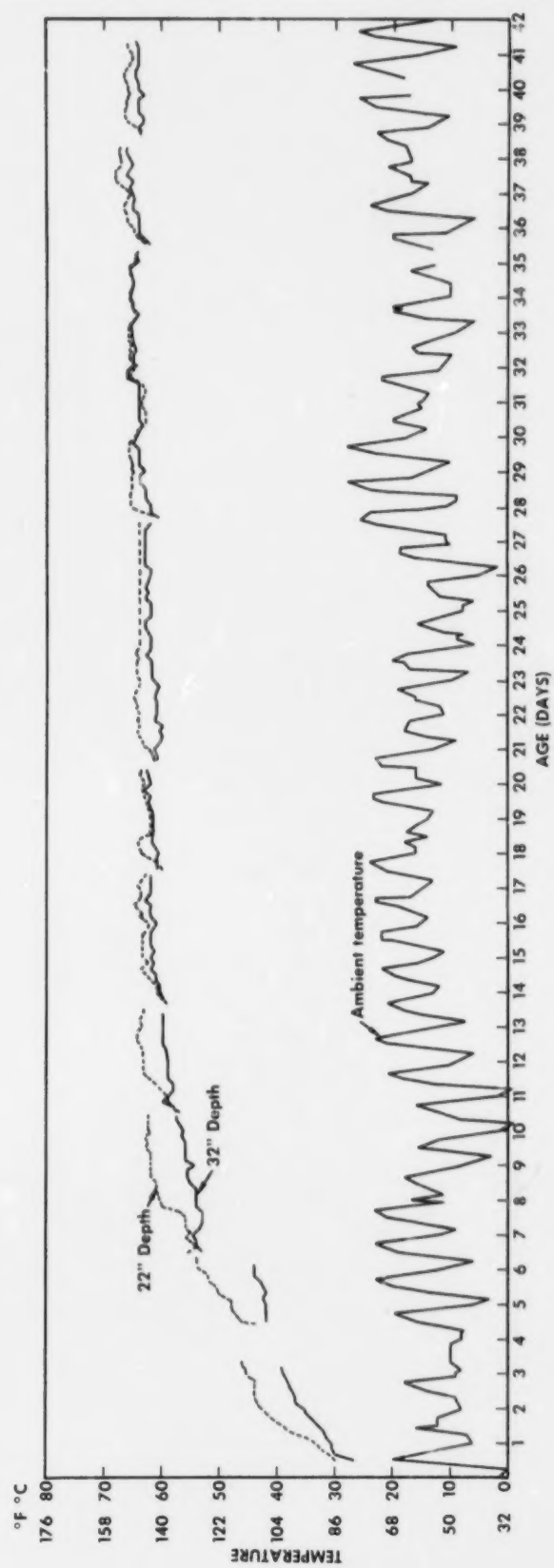


Figure 28. Temperature profile of windrow 17E.

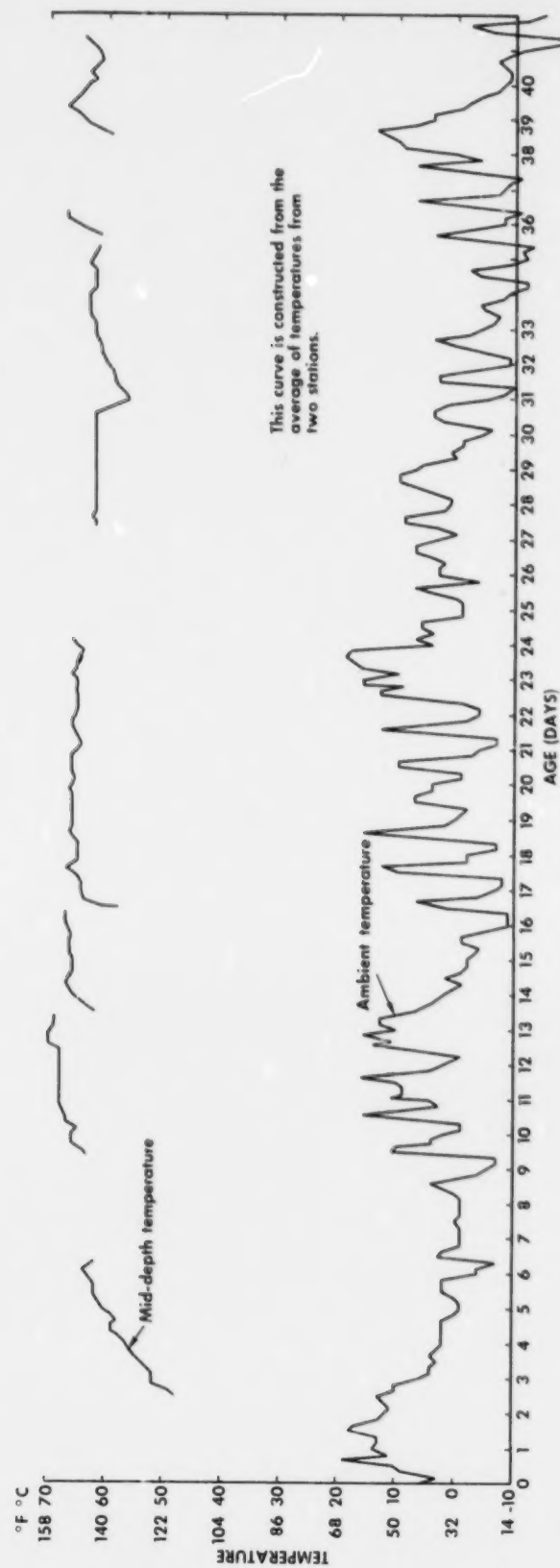


Figure 29. Temperature profile of windrow 17H.

shows the curve constructed from the averaged readings at mid-depth at the two stations over 42 days of composting. Ambient temperatures were low, reaching 5 F. The profile for this windrow, however, did not show the depressed temperatures exhibited in Figure 23. Figure 30 shows the relationship of position to temperature at various locations around this windrow at a depth of 8 in. and at mid-depth in the period of 31 to 35 days of composting. The higher temperatures in the upper parts of a windrow and the difference for the south and north sides are to be noted.

Conclusions to be drawn from these detailed observations of temperature are:

1. Temperatures vary with depth in all windrows. Temperatures above 140 F (60 C) are reached and maintained for significant periods of time in the inner mass of windrows.
2. These variations are more pronounced early in the composting cycle.
3. Immediately after turning, the temperature at all channels were found to be within 3.6 F (2 C) of one another.
4. After a turning, windrows quickly return to the temperature existing before the turning (Figures 25 and 28).
5. Excepting the outside 8 in. of material, weather conditions appear to have little effect on the windrow temperatures.
6. The surface temperatures at the apex of the windrows were often observed to be as high or sometimes higher than the mid-depth temperature.

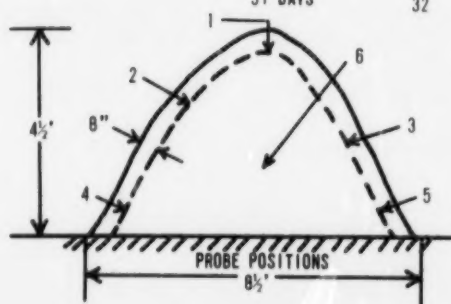
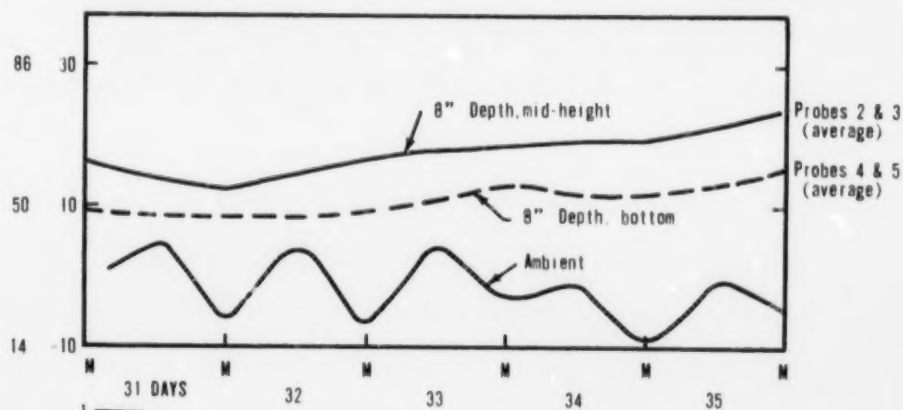
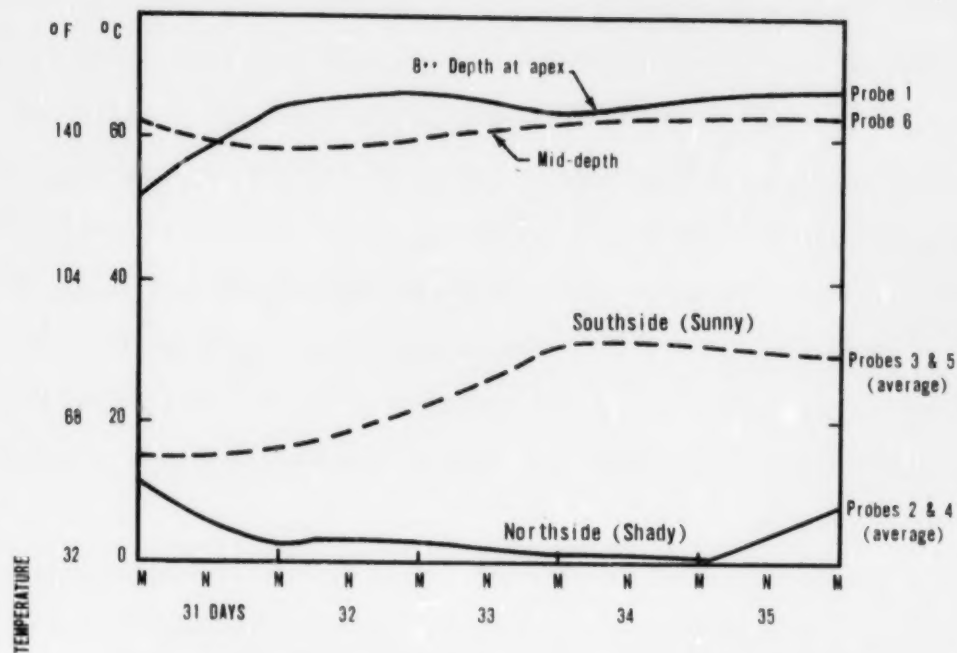


Figure 30. Temperature profiles at the 8" depth of windrow 17H (Nov. 4, 1968-Dec. 30, 1968).

7. The temperature on the outside 8 in. of the windrow decreased from the apex to the ground. This is considered due to convection currents rising from the bottom to the top inside the windrow. It is interesting to note that these may aid in the aeration of the compost.

8. The surface temperatures on the north or shady side of windrow 17H were observed to be lower than those on the south or sunny side.

Effect of Windrow Turning Frequency. Ten windrows were studied for the effect of various turning schedules. The number of turnings during the 49-day cycle for these windrows was 0 to 14. Temperatures were taken once a week throughout the test period. The relative degree of decomposition attained was judged on the basis of appearance, odor, and the amount of carbohydrate reduction.

The present windrow turning schedule is twice a week for the first 3 weeks and once a week thereafter. This routine was based on the higher temperature pattern reached with this schedule, compared with the greater cost of turning more often with lower temperatures resulting. The minimum number of turnings which will result in satisfactory compost is once a week for the entire cycle.

It was found that the best decomposition in the 49 days was obtained by turning the windrow twice each week throughout the cycle. This windrow did not show as good a temperature pattern as the one turned on the present schedule (which attained the highest overall temperatures). It did, however, attain temperatures higher than any windrows turned fewer times.

The windrow on the present schedule showed the next best decomposition and attained the highest overall temperatures.

Other windrows, turned less frequently, showed decreasing temperatures. After turning these windrows, however, the temperatures rose 20 to 30 F within 5 days and then declined. The temperature in the windrow not turned rose to about 130 F in 14 days, then dropped steadily throughout the remainder of the test.

Effect of Composting Sewage Sludge with Refuse. Assuming that:

1. a population generates refuse at the rate of 5 lb per day per capita (a figure near the national average) and that it is received at the compost plant containing 35 percent moisture by wet weight, and
2. that raw sewage sludge solids of the same population are generated at 54 grams or 0.119 lb per capita per day, dry weight, and
3. that rejected noncompostables will amount to 26 percent of the incoming refuse,

the percentage of dry compostable material (sludge and "picked" refuse) represented by the dry sewage sludge solids is:

$$100 \times \frac{0.119}{0.119 + (5 \times .65 \times .74)} = 4.7 \text{ percent}$$

or about 5 percent. This is the proportion of sludge to refuse to be normally expected from the same population producing the refuse.

At Johnson City, although the per capita production of refuse is lower than average, the available sludge handling equipment limits the amount

added to refuse to between 3 and 5 percent of the total dry weight of the refuse-sludge mixture for normal operations. Obtaining a uniform sludge content has not been possible.

Using temperature as a parameter of composting activity, three pairs of windrows were closely observed. In each case a pair consisted of one windrow containing raw sludge and one of refuse alone. Figures 31, 32, and 33 show the temperature profiles for pairs having windrows containing 2, 3-5, and 9 percent sludge solids, respectively. Temperatures were taken at a depth of 1-1/2 ft. The conclusion drawn is that the amounts of sludge being processed, and even up to 9 percent sludge solids, had no significant effect on the temperatures reached in composting.

Figure 34 shows the pH profiles of a pair of windrows, one of which contained 2 percent of raw sludge solids by dry weight. No significant effect of sludge can be observed. Figure 35 shows the average pH values at various ages for a number of windrows with 3 to 5 percent raw sludge solids and a number of windrows without sludge. Figure 36 shows curves for a pair of windrows, one of which contained 9 percent raw sludge solids. Here a difference in the pH of the masses was observed, the value being higher in the earlier stages in the windrow containing sludge. The effect of the addition of sludge solids in amounts greater than would normally be the case is treated below in a discussion of a special study.

Assuming 0.85 percent nitrogen in fresh ground refuse and 3 percent in sludge solids, the use of sludge in the amount of 5 percent of the

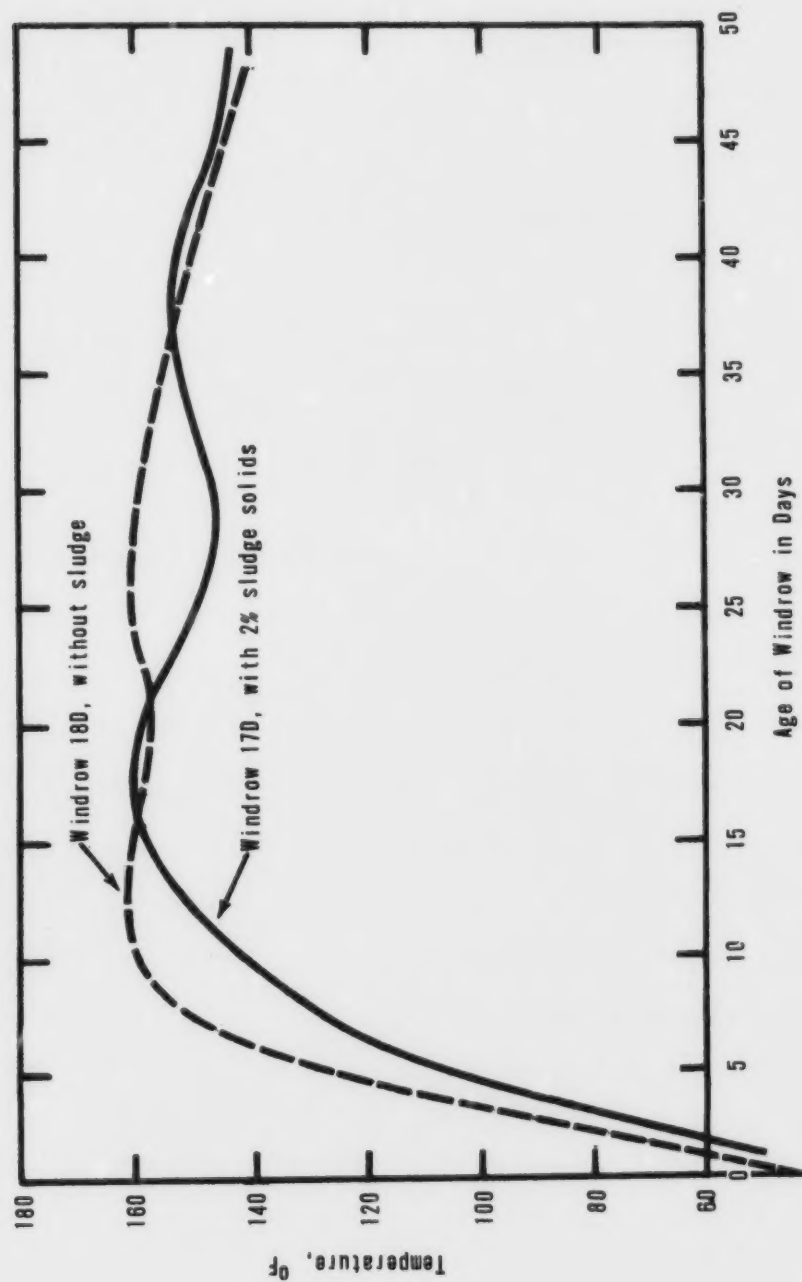


Figure 31. Temperatures in windrows with 2 percent sludge solids (1-1/2-ft depth).

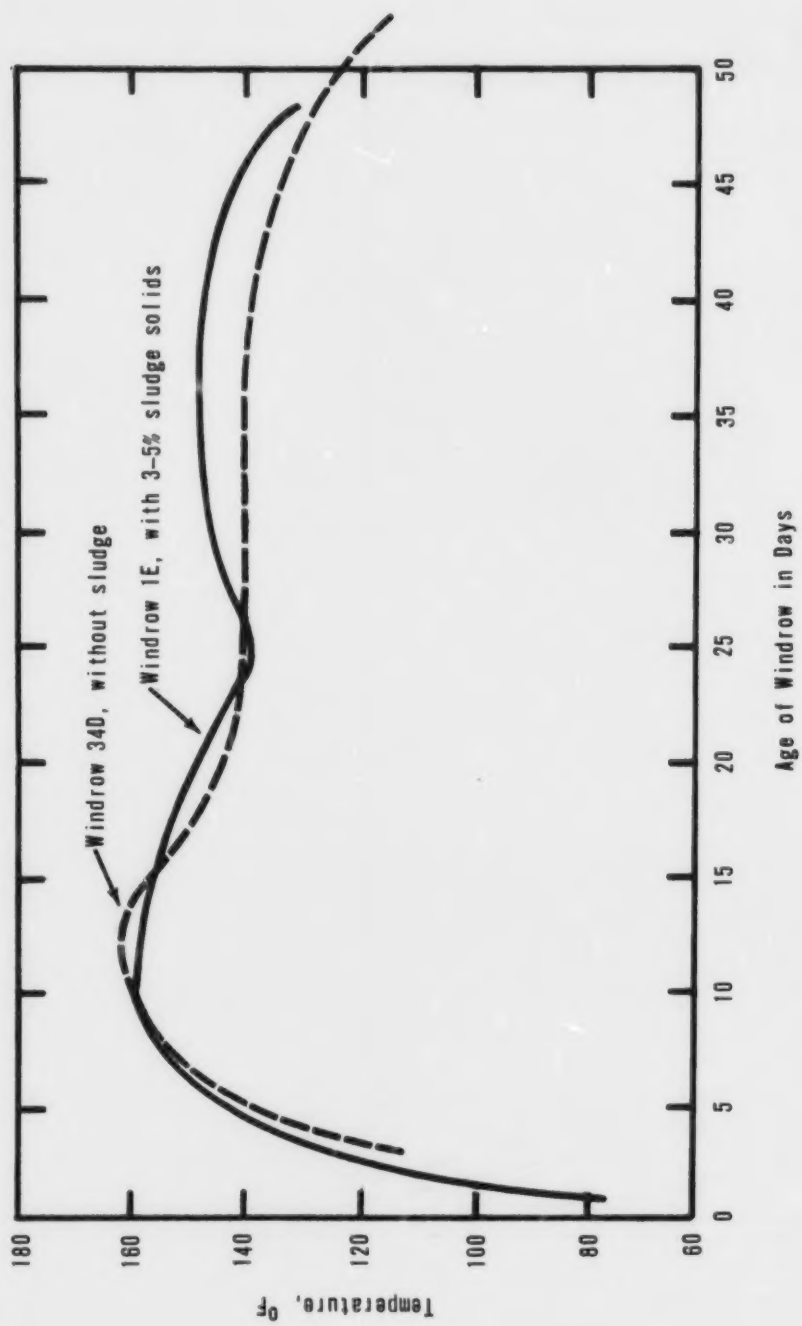


Figure 32. Temperatures in windrows with 3-5 percent sludge solids (1-1/2-ft depth).

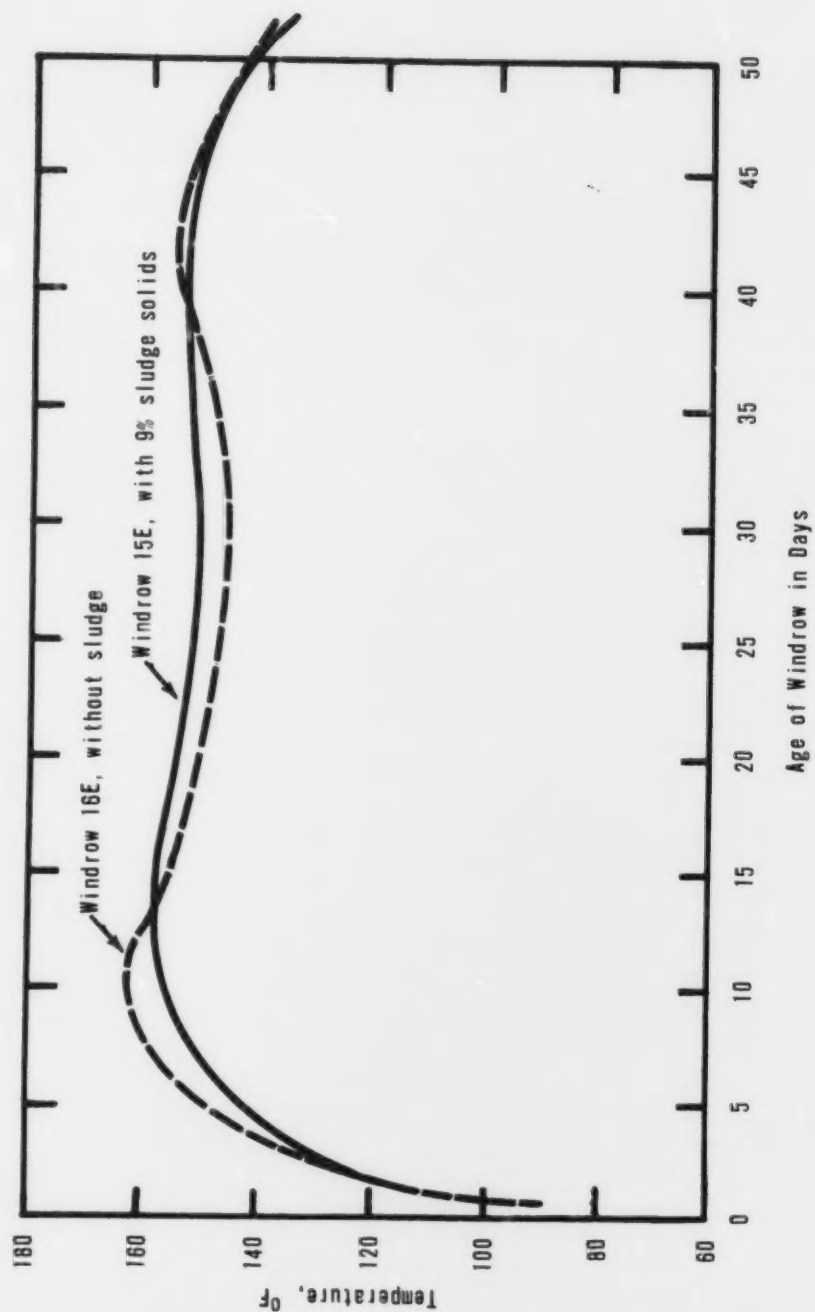


Figure 33. Temperatures in windrows with 9 percent sludge solids (1-1/2-ft depth).

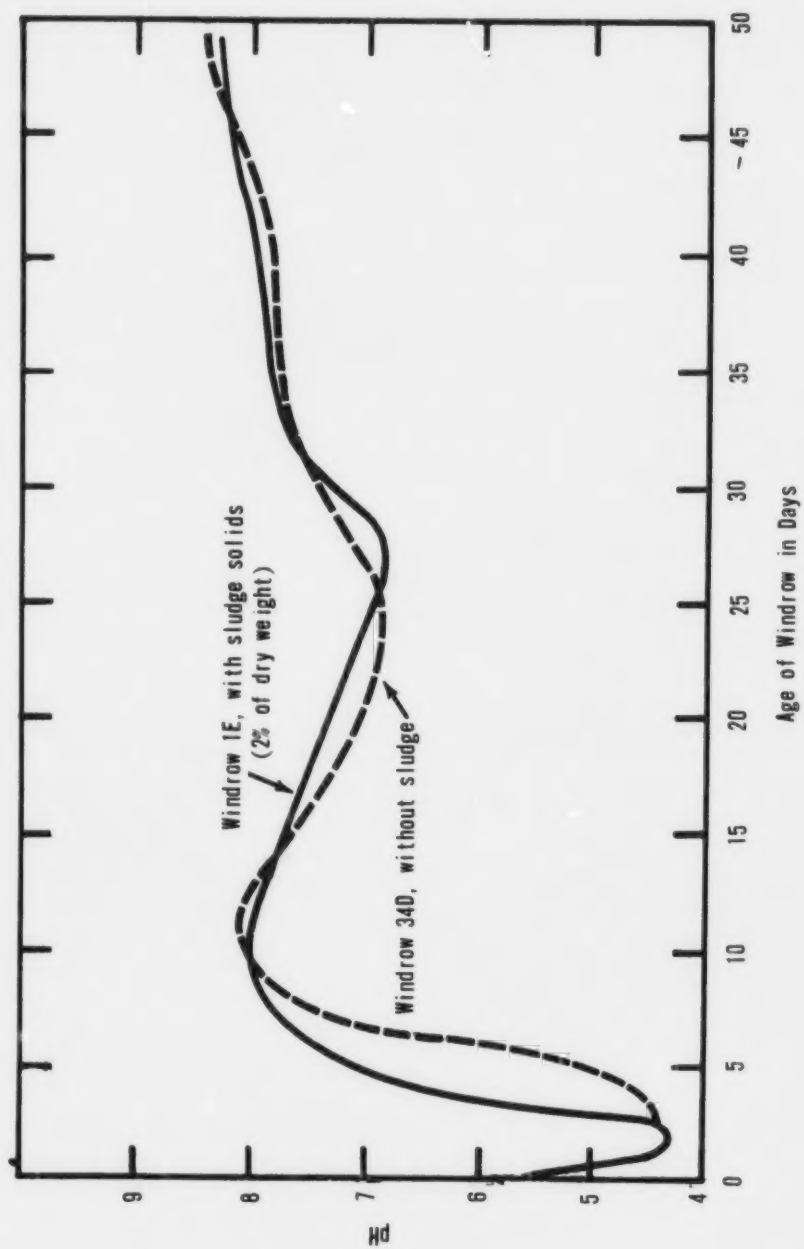


Figure 34. pH of windrows with 2 percent sludge solids (1-1/2-ft depth).

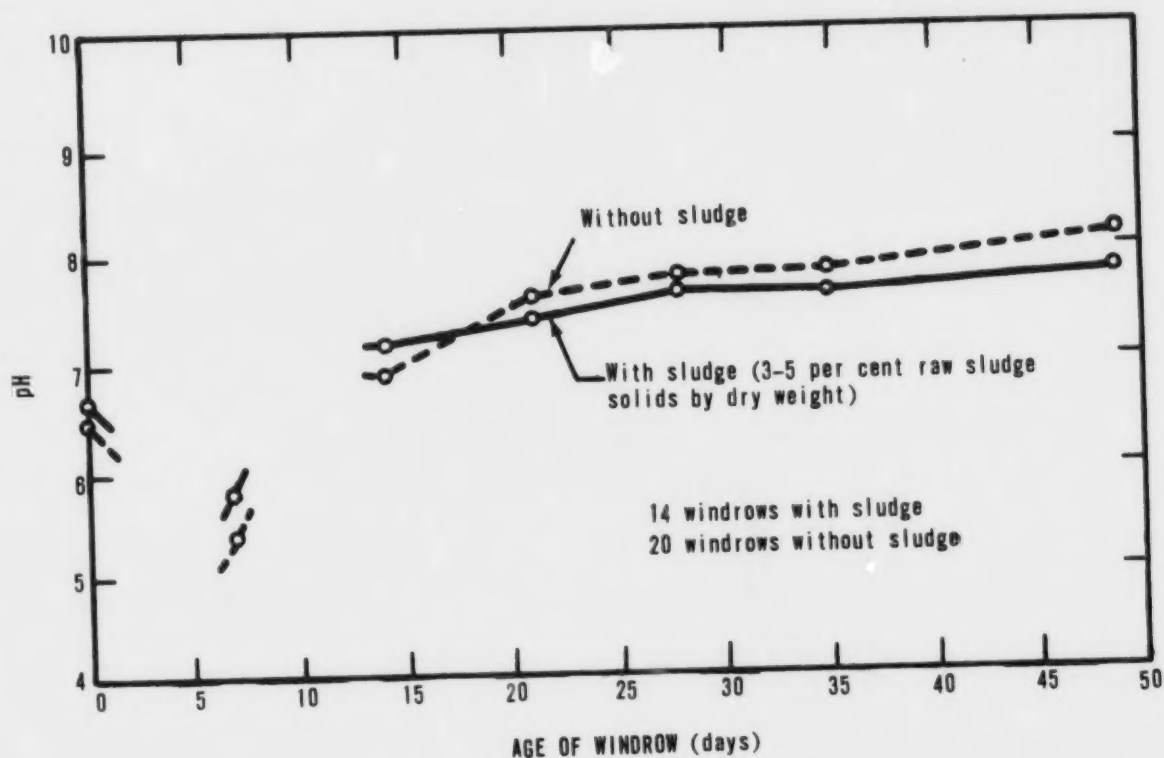


Figure 35. Average pH of windrows with 3-5 percent raw sludge solids (1-1/2-ft depth).

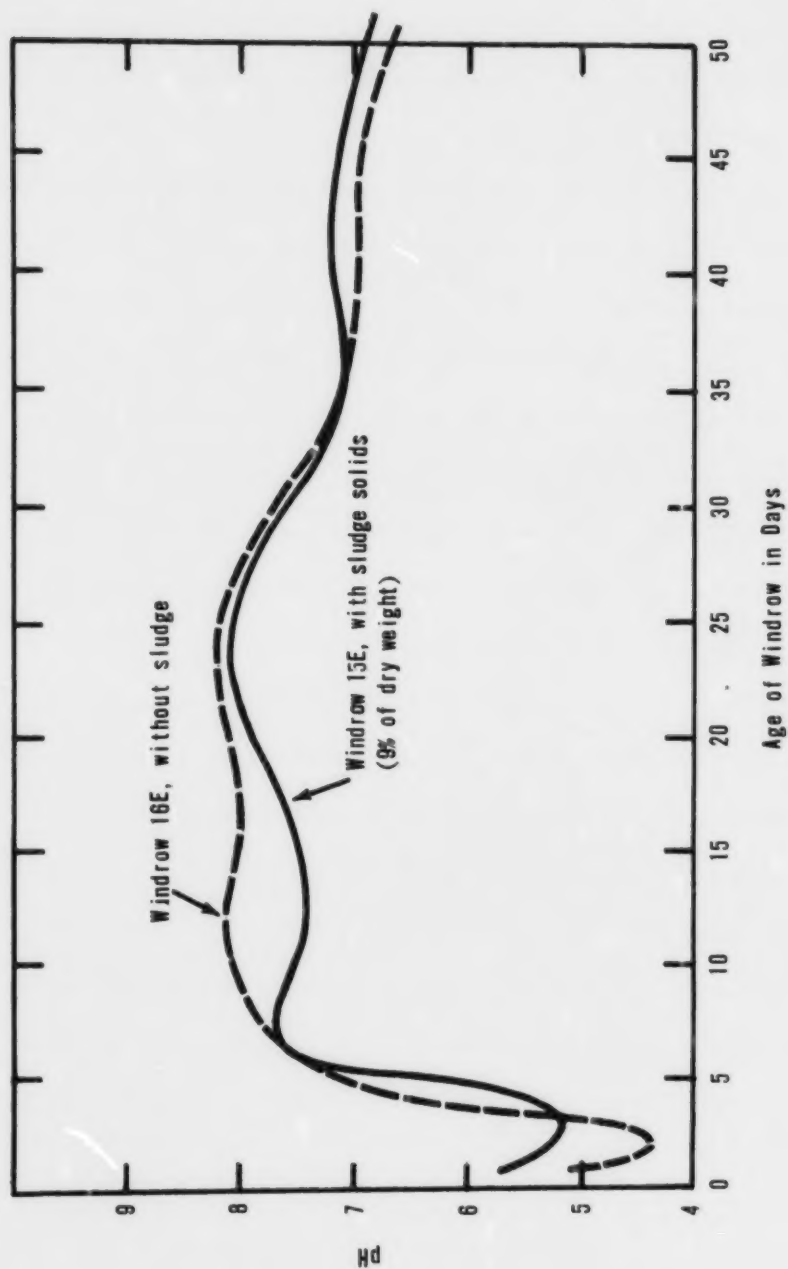


Figure 36. pH of windrows with 9 percent sludge solids (1-1/2-ft depth).

sludge-refuse mixture (dry solids basis) would result in a finished compost containing 1.05 percent nitrogen. This calculation assumes that the loss in nitrogen and the loss in weight from sludge during decomposition is similar to the loss from refuse.

The addition of sludge in the quantities used does not significantly add to the quality of finished compost as gauged by the nitrogen content. At Johnson City, actual observations show the compost made of refuse and sludge to have a nitrogen content averaging about 1 percent by dry weight.

Although the carbon to nitrogen ratios of refuse and compost are discussed under a subsequent heading, the observed effect of sludge solids on this important relationship should be mentioned here. The initial C/N ratios of a group of seven windrows containing 3 to 5 percent sludge solids showed an average of 44.4. At 42 days of composting a similar group of five windrows showed an average of 33.9 and at 49 days two of these showed an average of 31.9. A special test windrow prepared without sludge showed an initial ratio of 44.4 and at 49 days a ratio of 33.0.

The observations of the rate of heating, the pH profile, and the C/N ratios lead to the conclusion that the addition of sludge in the amounts which would normally be available has no appreciable effect on the composting process for refuse similar to that collected in Johnson City. For refuse with a low organic content, the effect of the addition of this amount of sludge may be greater.

Several experiments were made with sludge in appreciably greater quantities than would normally be available.

Sludge solids were added in the amount of 12 percent of the dry weight to a portion of a windrow. The heating pattern was observed to be normal. The initial nitrogen content of the control was 0.79 percent and that of the test portion 0.86 percent. The 49th day nitrogen content was 0.97 for the control and 1.02 for the test material.

Despite the low nitrogen content in these observations, the C/N ratio at 49 days was 25.4, lower and more favorable than normally observed at Johnson City. The texture and appearance of the compost was improved.

Another windrow was prepared with portion containing 33 percent in raw sewage solids from a neighboring city which uses a vacuum filter for dewatering. Initial nitrogen content was 1.64 percent for the test portion and 0.75 for the control portion. The final nitrogen content for the sludge-refuse compost was 1.58 percent and 0.88 for the control. Figure 37 shows that the temperatures rose along with those of the control for the first week, dipped, and then again reached those of the control in three weeks. Figure 38 shows the pH profiles of the test and the control. The initial pH was high at 9.0, then fell and gradually rose to well above that of the control at the same age.

The chemical oxygen demand (COD) of the control and the test portion were:

<u>Day</u>	<u>Test</u>	<u>Control</u>
1	940 mg/g	890 mg/g
28	710	775
56	590	670

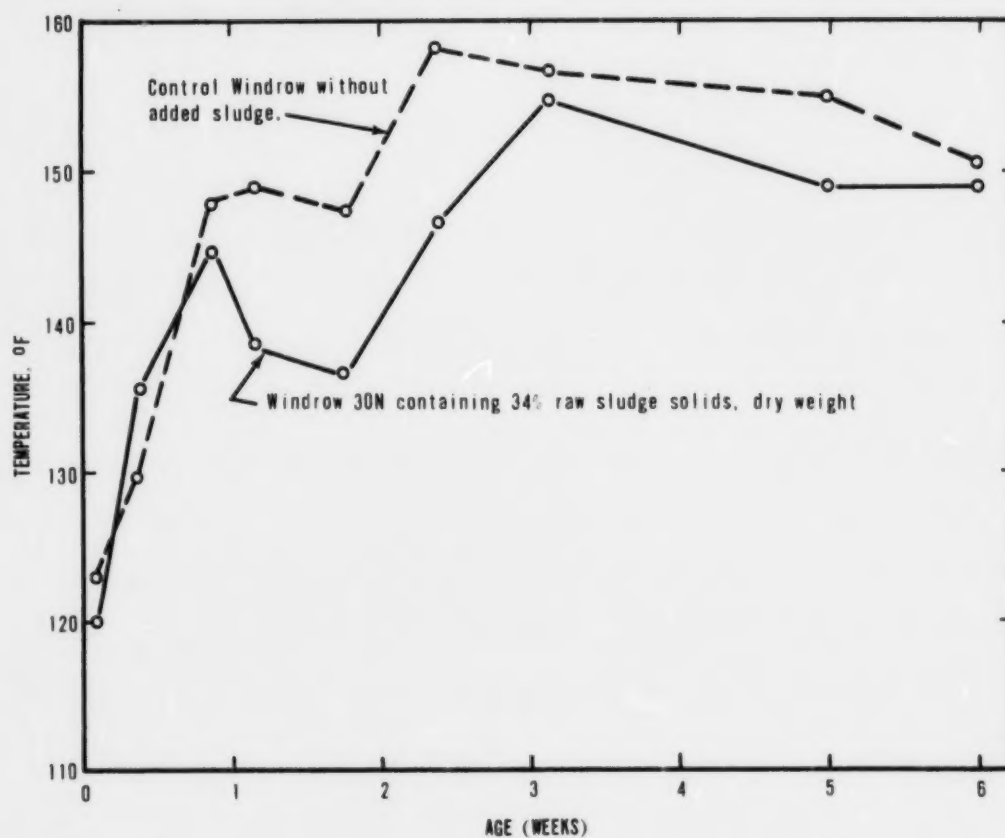


Figure 37. Temperatures of a windrow with 34 percent sludge solids (1-1/2-ft depth).

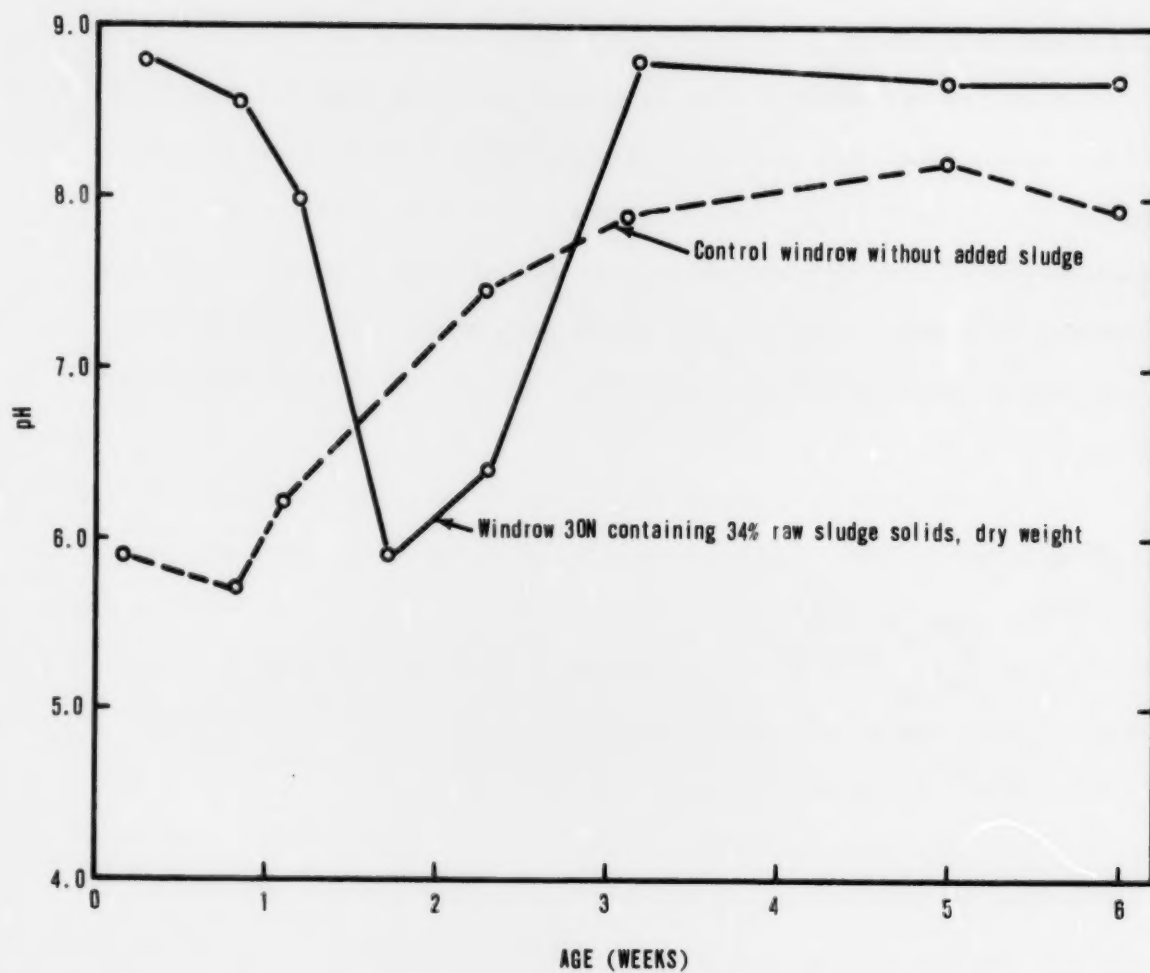


Figure 38. pH of a windrow with 34 percent sludge solids (1-1/2-ft depth).

The rates of decomposition did not differ greatly as measured by the reduction in COD. The final product benefited in nitrogen content from the sludge but some nitrogen had been lost in the process. The compost had a rich appearance.

A windrow was prepared with 50 percent partially digested sewage sludge solids taken from a dried up sludge lagoon. The temperature profile was similar to that of the control to the 2-week point after which temperatures of the test portion lagged. Satisfactory temperatures were, however, attained. The pH of the mass of test material showed a departure from that of normal refuse on composting. No nitrogen determinations were made (Figure 39).

It is concluded that sewage sludge solids can be successfully composted with municipal refuse. In the amounts normally available, the proportion of sewage solids to refuse will not greatly affect the rate of decomposition or the quality of the finished compost as measured by nitrogen content. Where greater amounts are available, the nitrogen content and appearance of the compost can be improved.

Effect of Adding a Nitrogen Compound to Composting Refuse. Under the supervision of the TVA agriculturist, urea-ammonium nitrate containing about 27 percent nitrogen was incorporated into composting refuse in several tests. The windrows were kept under observation for temperature as a parameter of composting activity and the chemist performed the chemical tests and the moisture determinations. The observed effects are discussed as follows:

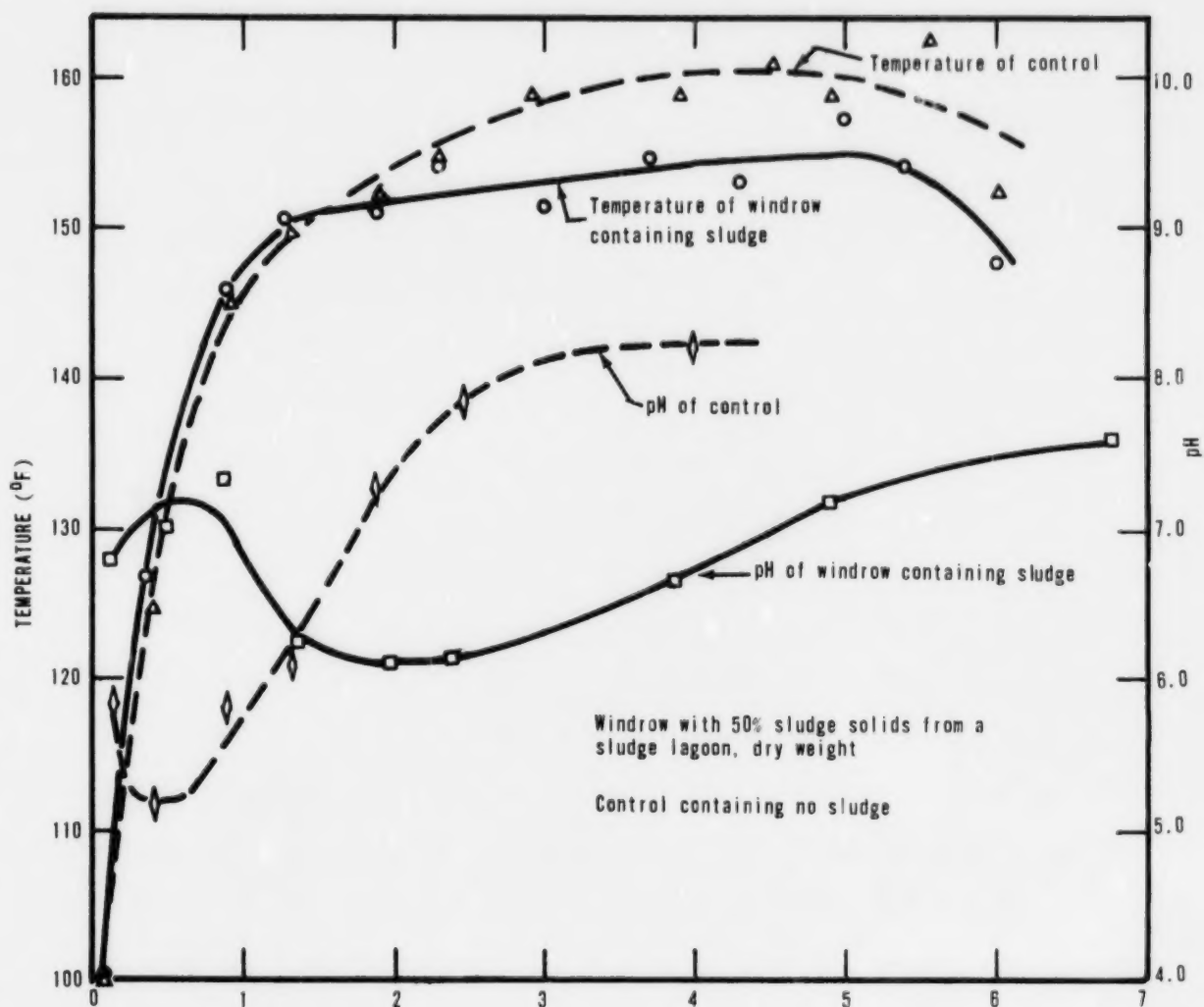


Figure 39. Temperature and pH of a windrow containing 50 percent sludge solids (1-1/2-ft depth).

Test 1. Enough urea-ammonium nitrate was added to a section of windrow 8G on day 1 to bring the nitrogen content from 0.94 to 3.5 percent by dry weight of the mass. This windrow contained raw sewage sludge and had a moisture content of 62.1 percent by wet weight. The second section was left as a control. It was immediately noted that the pH of the test portion was 8.2 against the normal 6.6 in the control. The pH did not thereafter drop to the low normal obtained in the control. At the 11th day, when the control was at pH 5.00, the test row showed a pH of 7.55. By the 14th day the test row pH was over 8 while the control was barely over 7. After 21 days the two remained close together with a pH slightly over 8. This change in pH appeared to be linked with the microbiological activity as the temperature in the test row lagged well behind and never reached that of the control.

Table 9 tabulates the data and Figure 40 shows the temperature curves. Decomposition was slowed and although the test windrow contained more nitrogen than did the control at 42 days, there had been a significant loss.

Test 2. Urea-ammonium nitrate was added to a section of windrow 17G to bring the initial nitrogen content from 0.93 to 2.46 percent by dry weight. This windrow contained raw sewage sludge. Again the initial pH was elevated as in Test 1 but by the end of 8 days was nearer that of the control than was observed in the case of Test 1. By 18 days the control reached a pH of 7 but the test portion was above 8. As in Test 1, the

TABLE 9

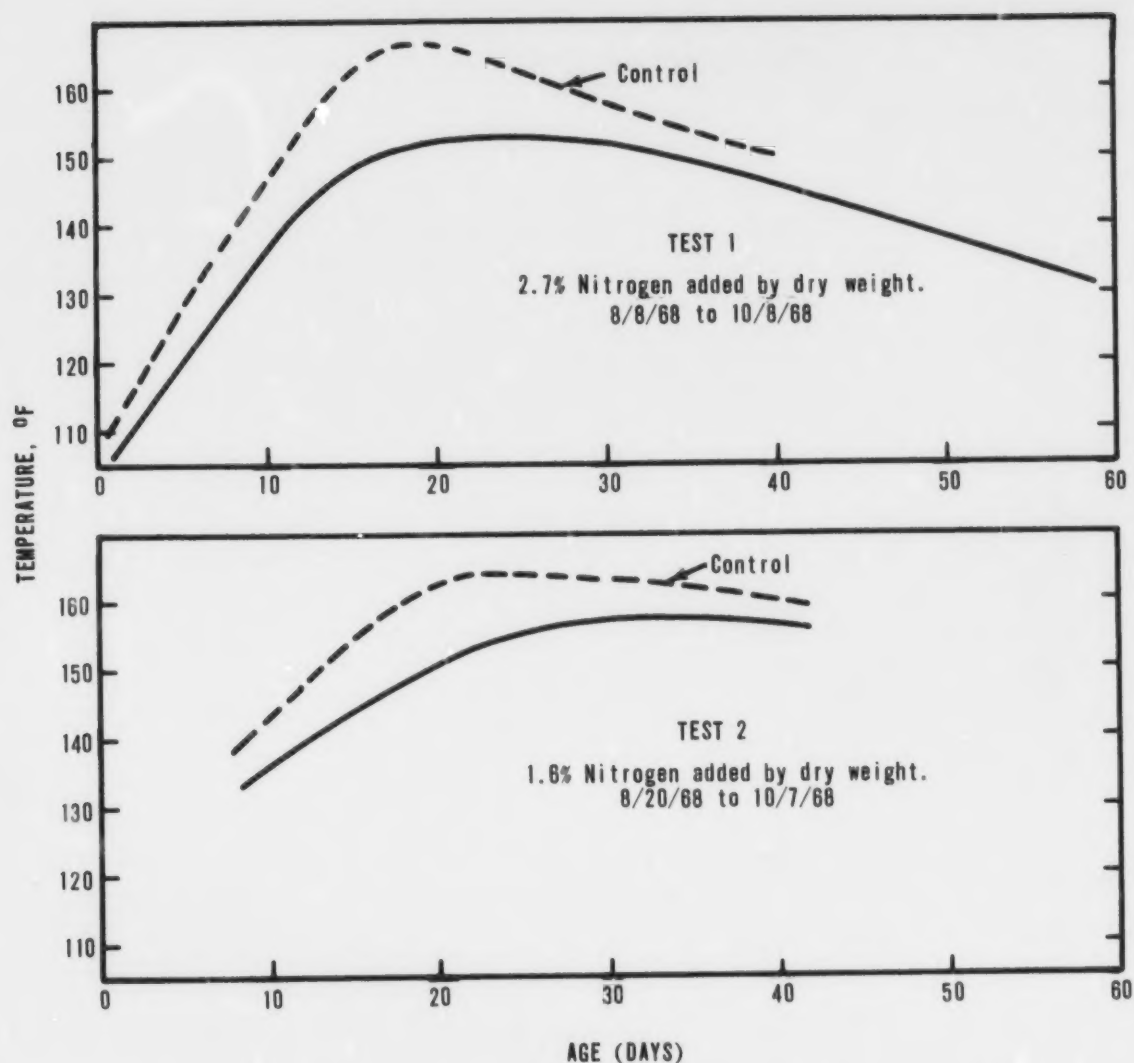
FRESH COMPOST FORTIFIED WITH NITROGEN
(Urea-Ammonium Nitrate)

Test 1 - Windrow 8G (8/8/68)

<u>Age in Days</u>	<u>% Nitrogen</u>		<u>Turning No.</u>	<u>% Moisture</u>		<u>pH</u>	
	<u>Control</u>	<u>Test</u>		<u>Control</u>	<u>Test</u>	<u>Control</u>	<u>Test</u>
0				61.1	62.1		
1	0.94	3.50	1			6.60	8.20
4			2				
5						4.70	7.10
8		3.47	3			4.68	6.08
11			4			5.00	7.55
14			5	43.2	43.2	7.08	8.08
15		3.68					
18			6				
21		3.11	7			8.50	8.35
28			8			8.30	8.25
34			9				
35		2.70				8.22	8.17
39			10				
42	1.14	2.75	11	49.6	38.6	7.90	8.18

Test 2 - Windrow 17G (8/20/68)

<u>Age in Days</u>	<u>% Nitrogen</u>		<u>Turning No.</u>	<u>% Moisture</u>		<u>pH</u>	
	<u>Control</u>	<u>Test</u>		<u>Control</u>	<u>Test</u>	<u>Control</u>	<u>Test</u>
1	0.93	2.46	1			6.22	8.10
3			2	72.3	72.3		
7			3				
8	1.01					4.60	5.30
10			4				
11		2.34					
14		2.51	5	58.5	57.0	6.00	7.90
17			6				
18						7.00	8.40
21		2.04	7				
28		1.85	8				
35		1.82	9				
38			10				
42		1.52					



(All windrows contained 2 to 5 percent raw sludge solids by dry weight)

Figure 40. Temperature of windrows containing urea-ammonium nitrate.

temperature of the test portion lagged and was not falling at the rate of the control at 42 days. As in Test 1, nitrogen was lost and microbiological activity was slowed as indicated by the temperature (Table 9 and Figure 40).

Test 3. In this test the urea-ammonium nitrate was added on the 21st day of composting in two windrows, 11M and 12M. Neither of these contained sewage sludge. In 11M, where the nitrogen content was raised to 2.35 percent by dry weight, the pH was immediately elevated and the temperature of the windrow dropped radically. By the 26th day the temperature had risen to about 150 F and was about normal thereafter. The final nitrogen content was 1.41 percent, showing a loss. In windrow 12M, the nitrogen content was brought up to 4.63 percent by dry weight. The pH reacted similarly to that of 11M but the temperature fell and remained low. The final nitrogen content was 3.35 percent, showing a loss (Table 10 and Figure 41).

Nitrogen had been added in an earlier test to windrow 1H on the 23rd day of composting, raising the nitrogen by about 1 percent of the dry weight of the mass. This windrow had reacted similarly to windrow 11M and 12M.

It is concluded from these tests that the addition of urea-ammonium nitrate in the amounts used appear to inhibit microbiological activity and result in a loss of nitrogen.

Effect of Adding a Buffering Agent to Composting Refuse. The pH of fresh refuse or refuse containing normal amounts of sewage sludge is about 6 and may drop to between 4 and 5 soon after being laid down for composting.

TABLE 10

AGED COMPOST FORTIFIED WITH NITROGEN
(Urea-Ammonium Nitrate)

Test 3 - Windrow 11M (7/10/69)

<u>Age in days</u>		<u>Percent Nitrogen Content</u>	<u>pH</u>
20	-----	-----	6.8
21	Nitrogen added -----	2.35 -----	3.1
24	-----	-----	8.0
28	-----	-----	7.8
35	-----	-----	7.8
42	-----	1.41 -----	8.1

Windrow 12M (7/11/69)

20	-----	-----	6.2
21	Nitrogen added -----	4.63 -----	8.3
24	-----	-----	8.2
28	-----	-----	7.9
35	-----	-----	8.0
42	-----	3.35 -----	8.2

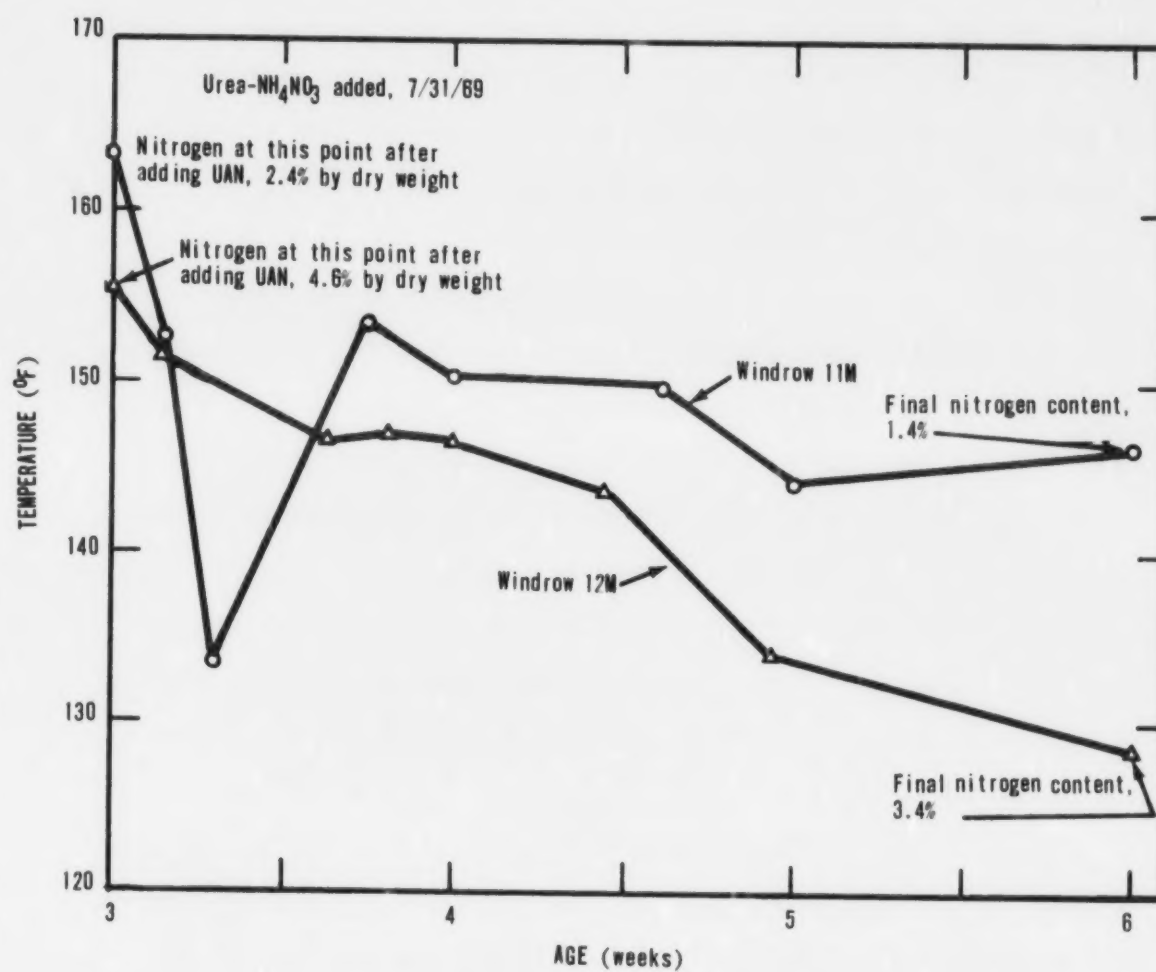


Figure 41. Temperature of windrows with urea-ammonium nitrate.

Often in farm and gardening practice crushed oyster shells, crushed limestone, or even lime is added to raise the pH at the start to accelerate decomposition. At Johnson City, three trials were run using limestone.

In the first trial, 3/16 in. crushed limestone was added in the amount of 21.2 percent of the total dry weight of the refuse-sludge-limestone mixture. The pH was raised initially to 7.5 but fell to 6 by the 16th day, after which it rose slowly to 8.5 on the 42nd day. The control was also atypical with respect to pH but exhibited the normal immediate drop from an initial 6 to 5.2 in 3 days after which it slowly rose to 8.5 on the 42nd day. The temperature of the test windrow rose more sharply than did that of the control but dropped after 10 days due to a deficiency of moisture. Water was added and the temperature rose again but not as quickly as would have been expected. The data for pH and temperature are shown in Figures 42 and 43.

Limestone dust was added at the rate of 9 and 16 percent by dry weight to two portions of a test windrow prepared from fresh refuse only. Figures 44 and 45 show the pH and temperature profiles of the test and control sections. The effect in each case was to raise the initial pH and both test sections showed an atypical rise and dip in pH in the first week. Again the attainment of high temperature was accelerated.

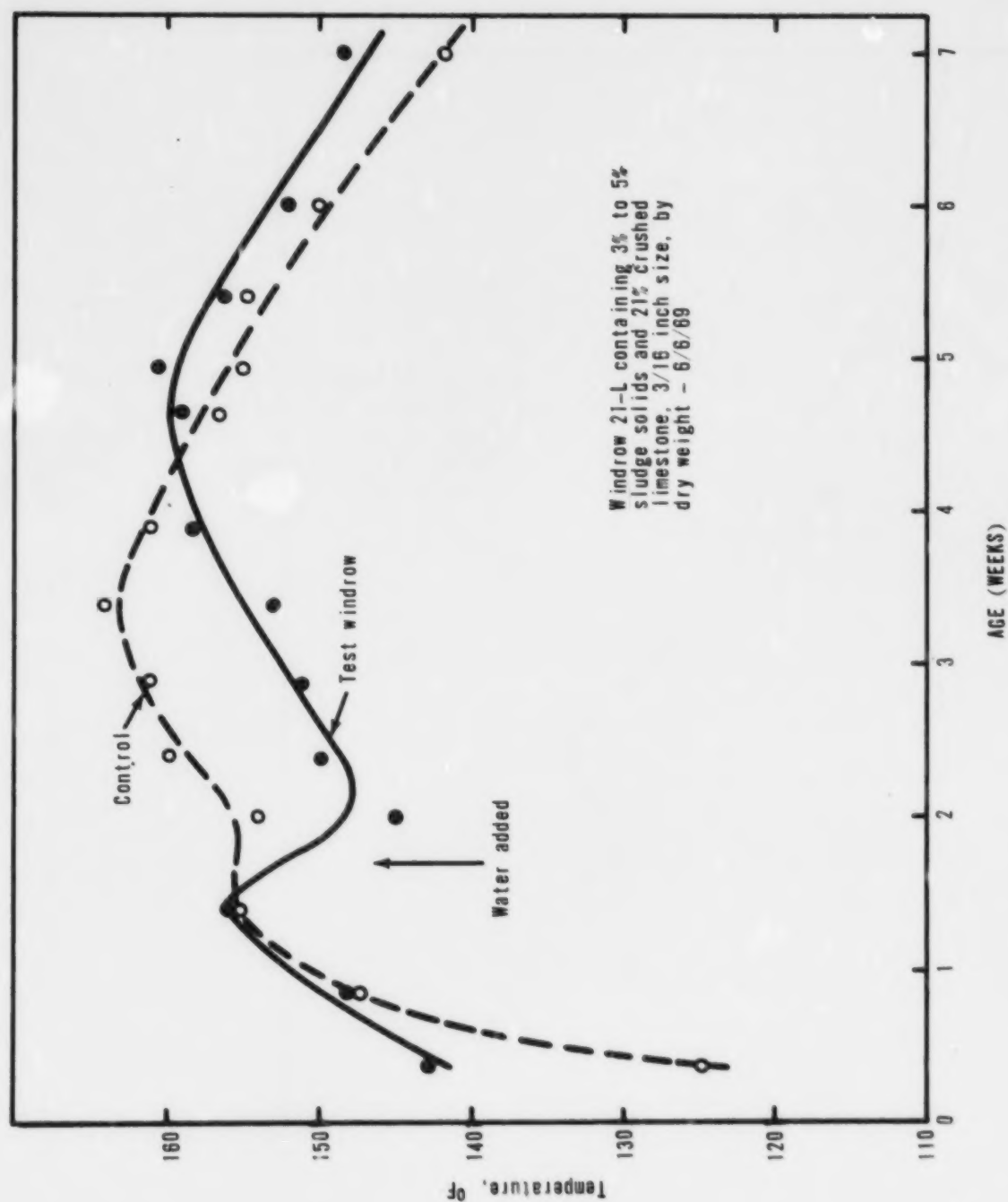


Figure 42. Temperatures of windrows with limestone and sludge added.

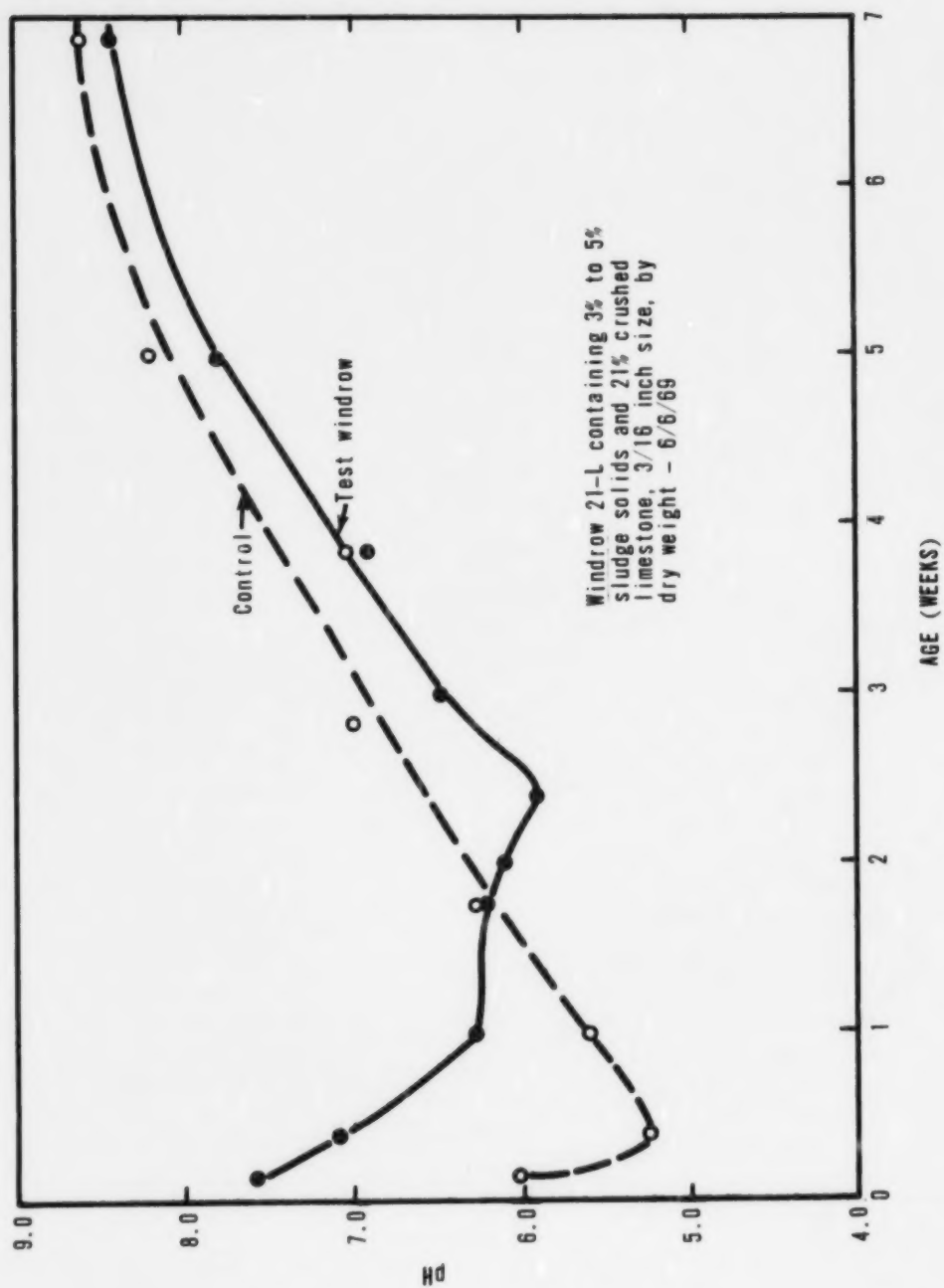


Figure 43. pH of windrow with limestone and sludge added.

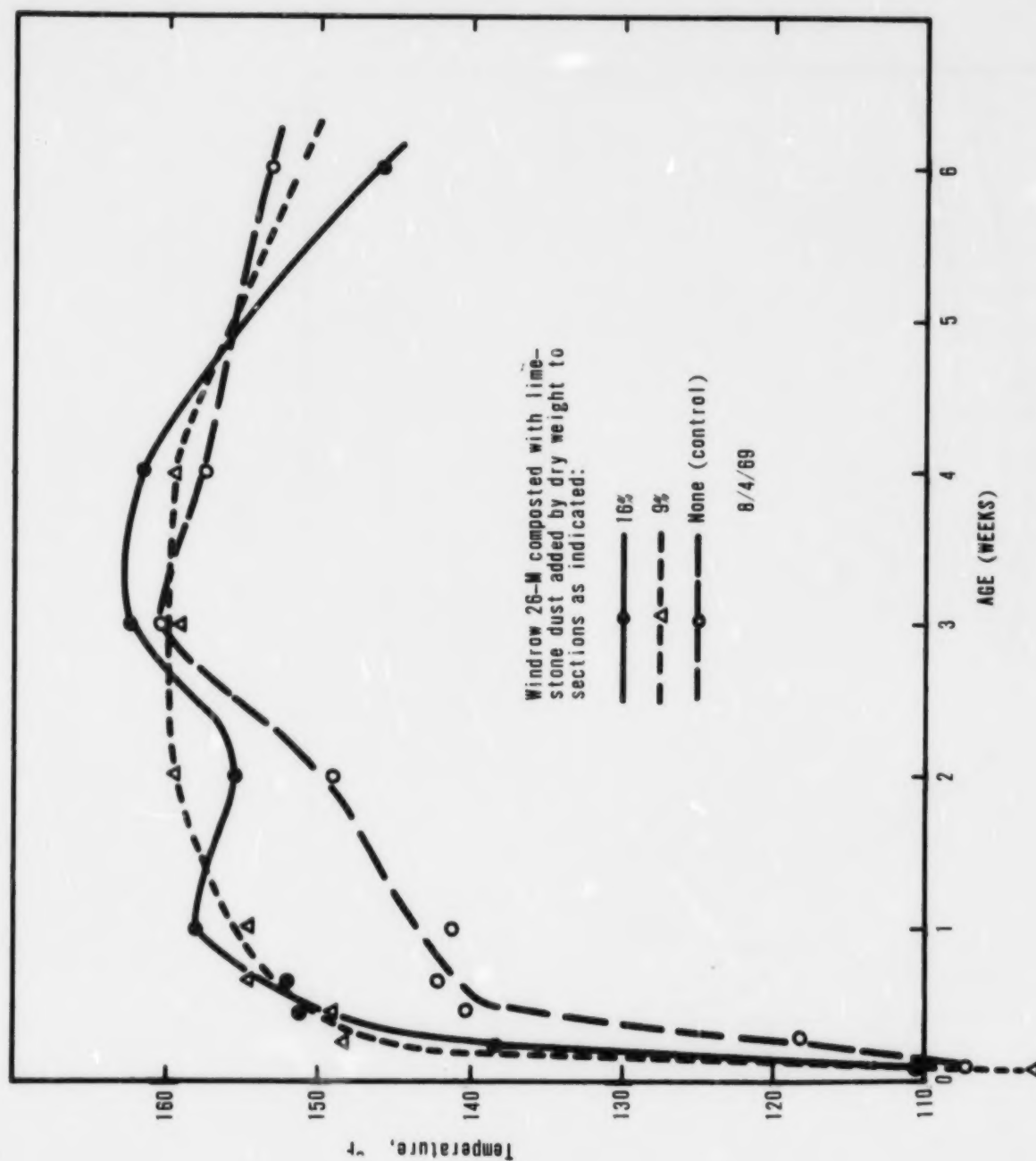


Figure 44. Temperature of windrow with limestone dust added.

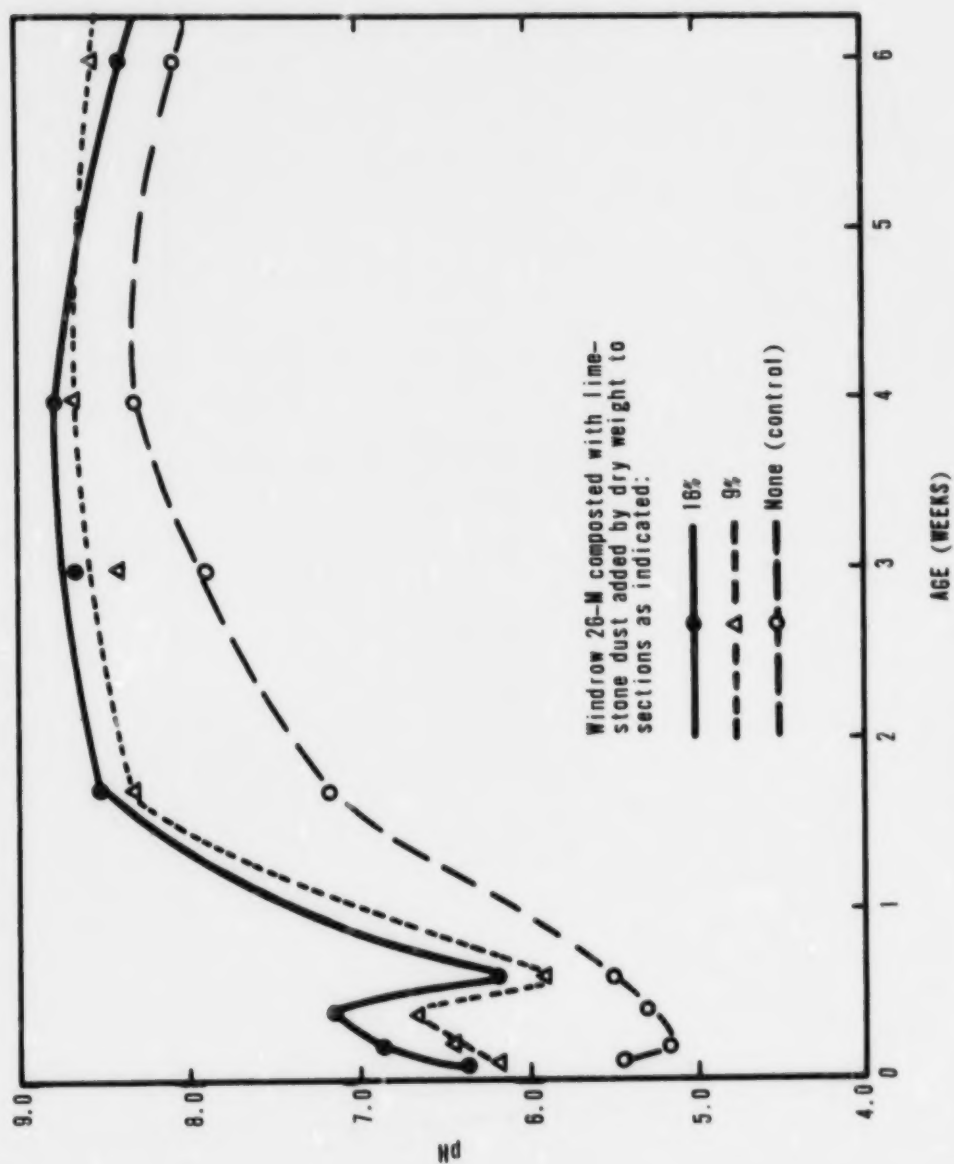


Figure 45. pH of windrow with limestone dust added.

Analysis for nitrogen showed the following:

Windrow	Additives	Nitrogen content by % of dry weight		
		0 day	21st day	49th day
<u>Test No. 1</u>				
Control	3 to 5% sludge solids	0.81		1.02
Test	Same as above with 21.2% 3/16" crushed limestone	0.74		0.57
<u>Test No. 2</u>				
Control	None	0.84	0.82	0.96
Test	9% limestone dust	0.73	0.76	0.66
Test	16% limestone dust	0.64	0.61	0.49

Although the temperature rise was accelerated, there was a considerable loss of nitrogen which resulted in a poorer compost. The results of these field tests are similar to those of the laboratory tests conducted by the University of California at Berkeley.²

Effect of Composting Other Wastes with Refuse. The TVA agriculturist obtained quantities of cow manure, paunch manure, aged poultry (chicken) manure, animal blood, and pepper canning wastes for incorporation into composting refuse to investigate the possibilities of this method of disposal of such wastes and to see if the finished compost was improved by addition of them. As with the windrows to which urea-ammonium nitrate was added, temperature was used as the parameter of composting activity. Tests with the several wastes are discussed as follows:

1. Cow manure, in an amount making it 15.4 percent of the mixture of manure and refuse by dry weight, was added on day 1 to a section of windrow 17N. No sewage sludge was incorporated in this windrow.

The initial nitrogen content of the mixture by dry weight was 1.12 percent and of the control 0.80 percent. Final nitrogen content for the composted mixture was 1.14 percent as against 0.93 percent for the control. Temperature was slow to rise, reaching in 4 weeks what had been reached in 2 weeks by the control (154 F). The pH of the mixture initially was lower than that of the control, 4.4 to 6.2. The pH of the control dipped then rose characteristically to nearly 8 in 2 weeks at which time the mixture also had reached the same value. Decomposition of the mixture in this proportion, as indicated by temperatures, appeared to be slowed and the mixture would have to remain on the field longer than refuse alone (Figure 46).

2. Paunch manure from a local slaughterhouse, in an amount equal to 14.9 percent of the mixture by dry weight, was added on day 1 to a portion of windrow 13G. This windrow contained between 2 and 5 percent raw sewage sludge by dry weight. The initial nitrogen content of the mixture was 1.22 percent against 0.97 percent for the control. The paunch manure itself contained 2.48 percent nitrogen by dry weight. The temperature curves for the 42 days of composting were identical for the test and control portions. The 42-day nitrogen of the test row was 1.26 percent and of the control 1.04 percent. Figure 47 gives the temperature curve.

3. Chicken manure, in an amount equal to 21.2 percent of the mixture by dry weight, was added on day 1 to a portion of

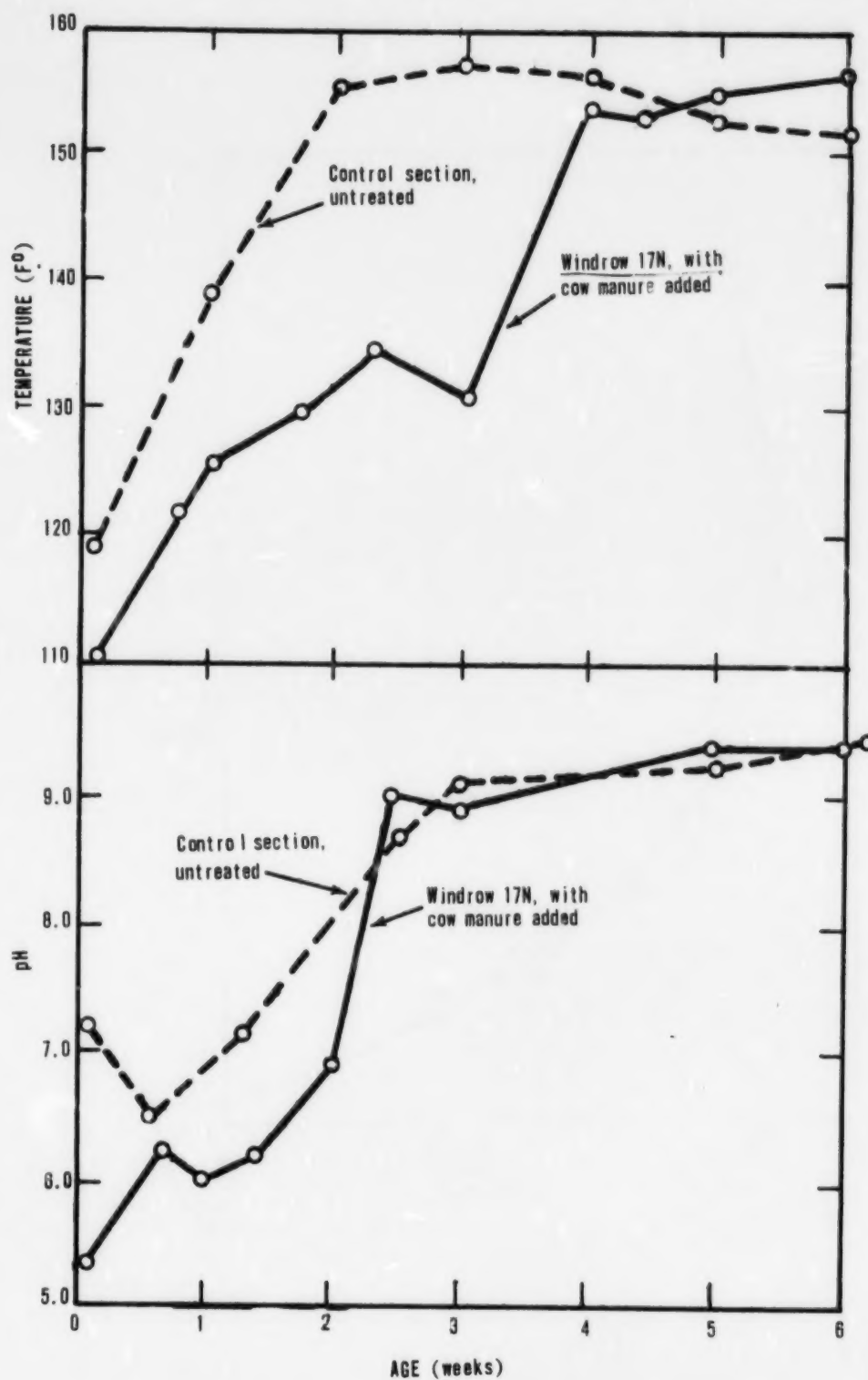


Figure 46. Temperature and pH of refuse composted with cow manure.

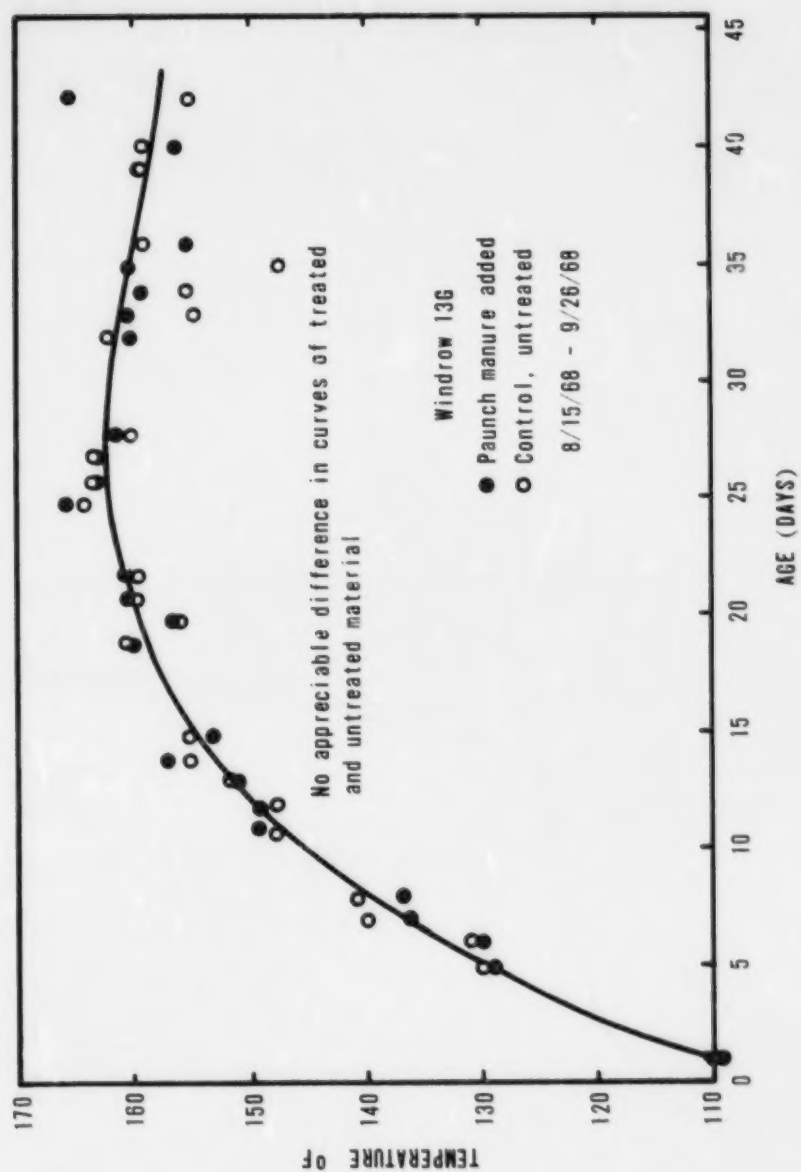


Figure 47. Temperature of refuse composted with paunch manure.

windrow 19C. The chicken manure had been made available to the project on the occasion of a clearout of droppings from a local farm. A portion of it had undergone decomposition for as much as 6 months. Its nitrogen content was 2.40 percent, similar to that of paunch manure, and the initial nitrogen content of the mixture was 1.37 percent and of the control 0.84 percent. The raw refuse contained between 2 and 5 percent sludge solids. Although the initial nitrogen content of the two portions was not greatly different from those of the paunch manure test, the test portion reached its maximum temperature more quickly than did the control. On day 16 the test portion had reached 165 F while the control showed only 150 F (Figure 48). In this experiment the control did not act normally but the chicken manure hastened the activity in this particular batch of compost. The 42-day nitrogen content of the test portion was 1.25 percent against the 1.05 percent for the control.

The experiment was repeated with fresh chicken manure in windrow 15N with a concentration of 20.1 percent. This windrow contained no sewage sludge. Initial nitrogen content was 1.19 percent for the mixture and 0.73 percent for the control. Final nitrogen contents were 1.32 for the experimental portion and 0.99 percent for the control. The temperature of the portion containing the chicken manure approximately followed that of the control to about the third week when the profile for the test row fell below. By four and a half weeks the test portion was about 12 degrees

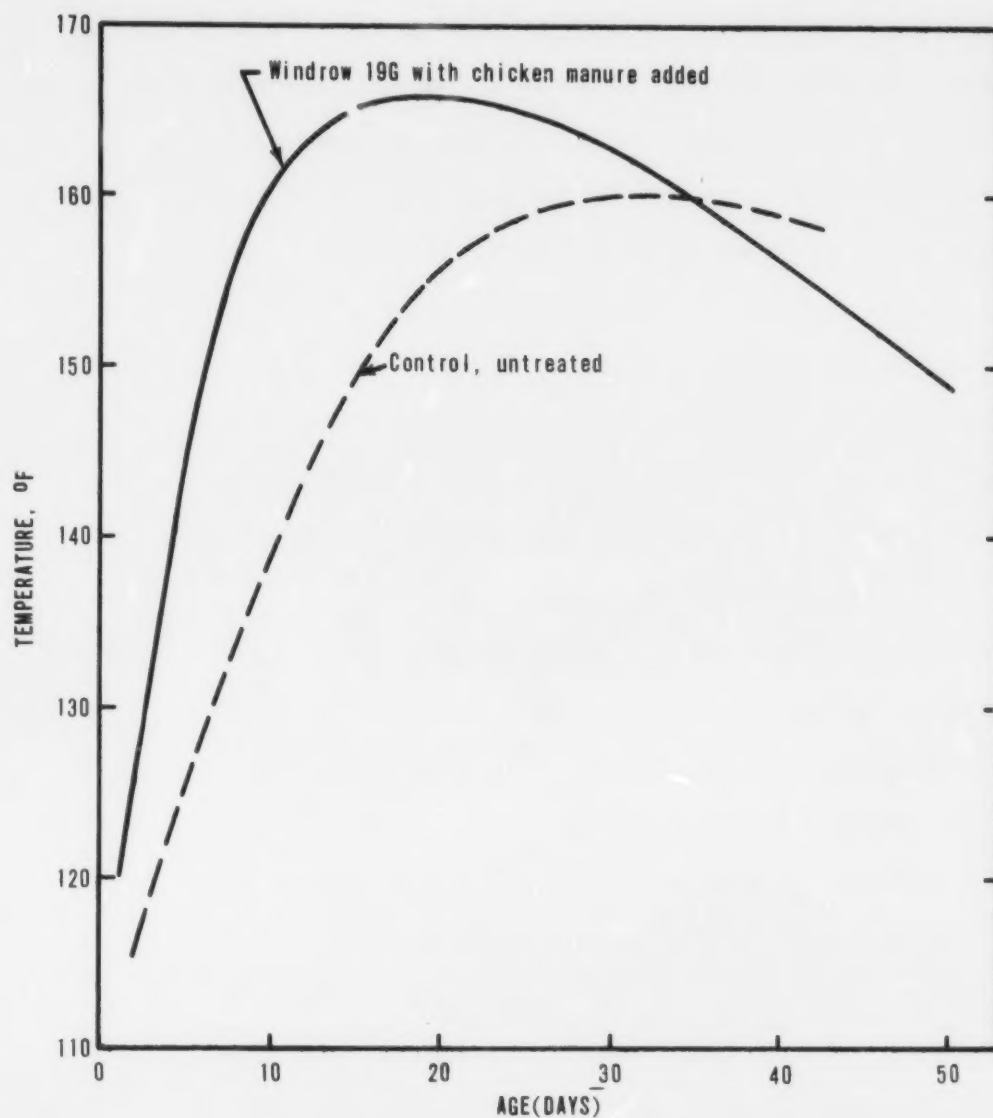


Figure 48. pH of refuse composted with aged chicken manure.

below that of the control. It then began to pick up and at the end of 6 weeks was again approximately that of the control. The pH of the mixture reached 8.8 when the control had reached 8. At 6 weeks the pH of the mixture was still somewhat higher than that of the control (Figure 49). The fresh manure and the composting mixture released large amounts of ammonia which accounts for the high pH and the lower temperatures observed.

4. Beef blood from a small slaughtering establishment was added on day 2 to a portion of a windrow containing about 3 percent sewage sludge solids. The 40 gallons of blood, weighing 354 lb, contained about 110 lb of solids. The mixture of refuse, sludge, and blood contained about 1.3 percent blood solids by dry weight. Blood is high in nitrogen, 10 to 14 percent by dry weight,⁴ and this rather small addition was estimated to raise the nitrogen content of the windrow from 0.91 percent to about 1.0 percent.

The addition of blood appeared to retard heating, as compared to the control portion, in the first 25 to 27 days. After that, the test portion exhibited temperatures exceeding those of the control (Figure 50). The 42-day nitrogen content for the test portion was 1.25 vs. the 1.05 of the control. This experiment showed that slaughterhouse blood can be composted with refuse without trouble and may have some value in enriching the compost. The experiment was not repeated due to the difficulty in obtaining blood and preserving it.

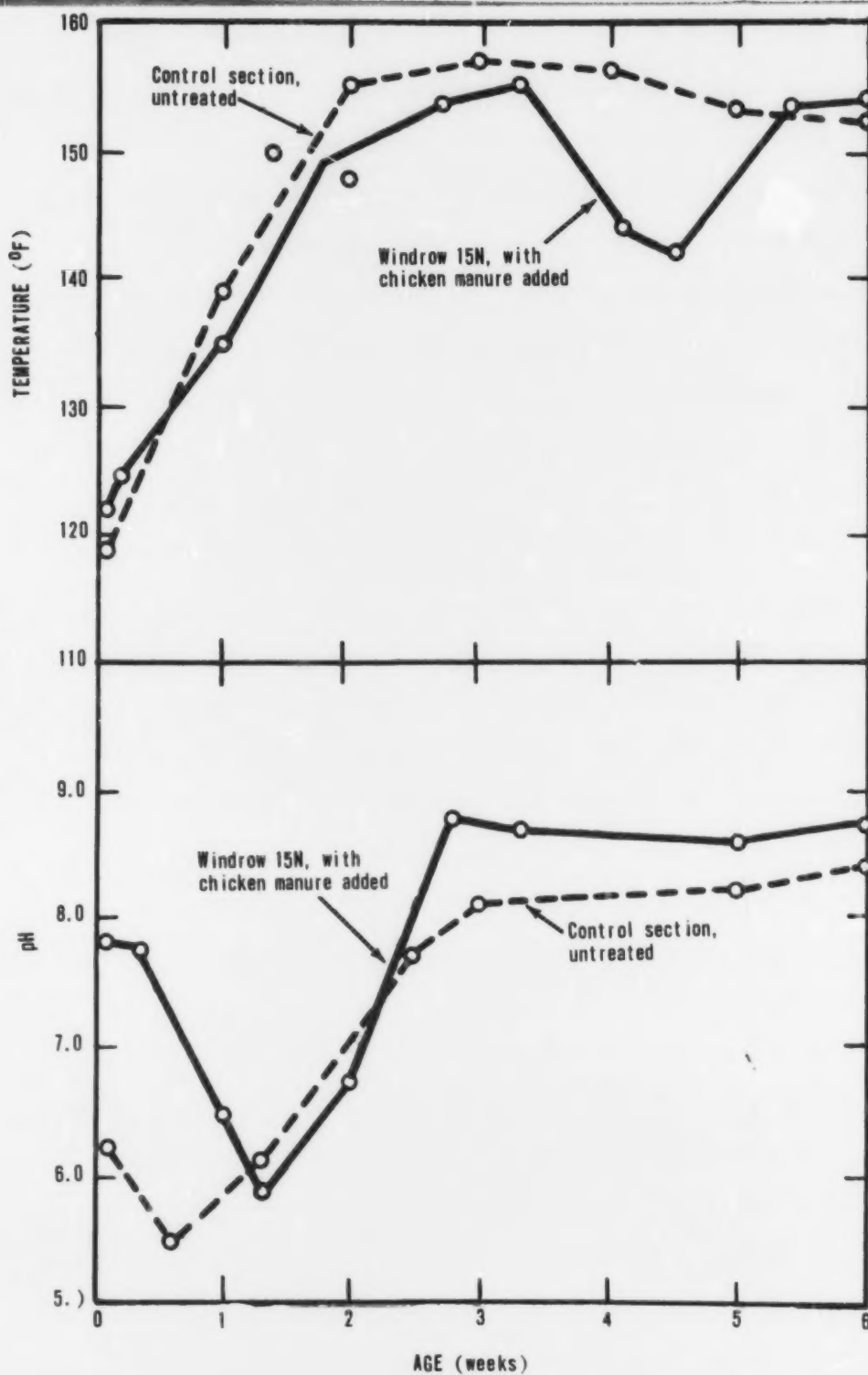


Figure 49. Temperature and pH of refuse composted with fresh chicken manure.

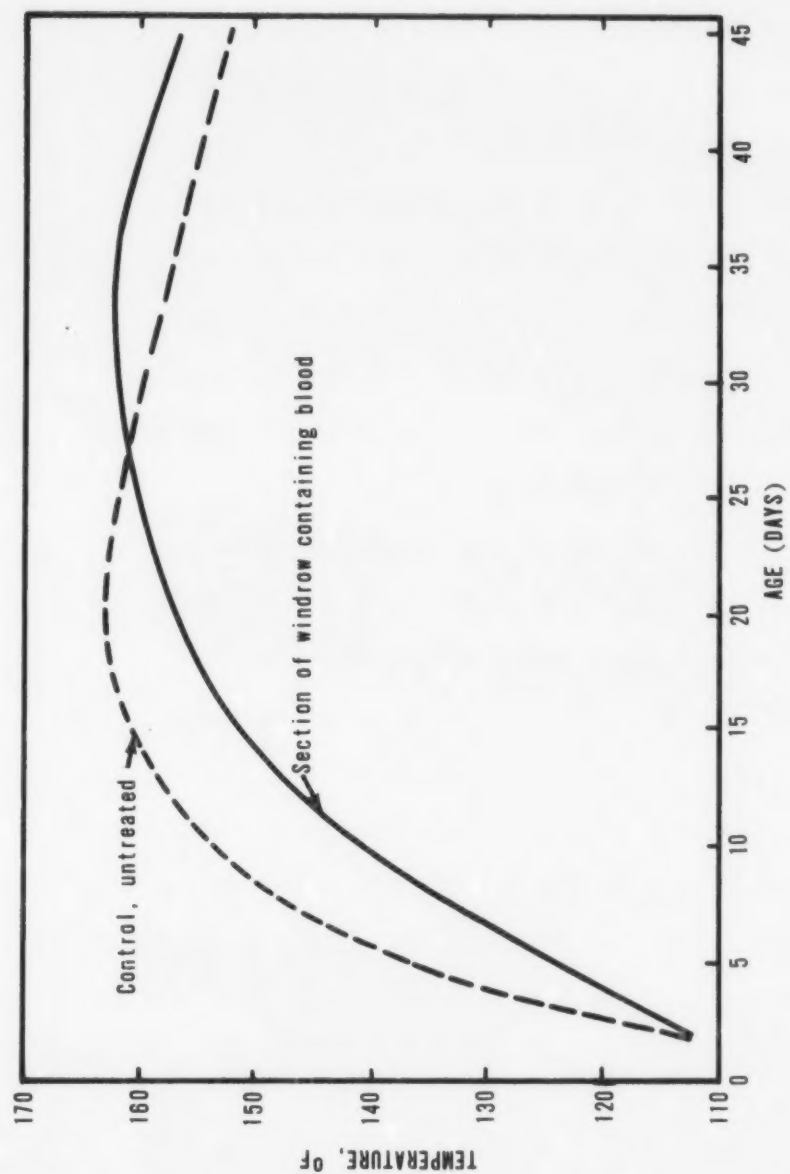


Figure 50. Temperature of refuse composted with slaughterhouse blood.

5. A batch of the wastes of a pimento pepper canning factory, consisting of the pepper cores, rejected peppers, and skins, was incorporated into a portion of a windrow of refuse containing about 3 percent sewage sludge solids on day 3. The pepper waste represented 14 percent of the total dry weight of the mix. The pepper wastes contained 2.82 percent nitrogen on a dry basis and the initial nitrogen content of the mix was about 1.1 percent. The temperature profiles of the test and control portions of the windrow were identical during the composting period. The final nitrogen content of the test portion was 1.3 percent.

This test was repeated using pepper canning wastes in the amount of 6.3 percent of the total weight of the mixture of refuse and pepper wastes. The pepper wastes contained 2.68 percent nitrogen in this case and the refuse (control portion) showed a nitrogen content of 0.89 percent. The initial nitrogen content of the refuse-sludge-pepper mixture was 1.04 percent. Figures 51 and 52 show the temperature and pH profiles during composting. The final nitrogen content (at 42 days) was 1.10 percent for the test row and 1.01 percent for the control.

Effect of Covering a Windrow with Plastic Sheeting. Half the length of a windrow was covered with plastic sheeting in April 1968 and the other half was left uncovered. The plastic was removed for turning and replaced immediately after turning. Temperatures were taken of both parts in the center and near the surface at a depth of 4 in. Some of these data are listed below.

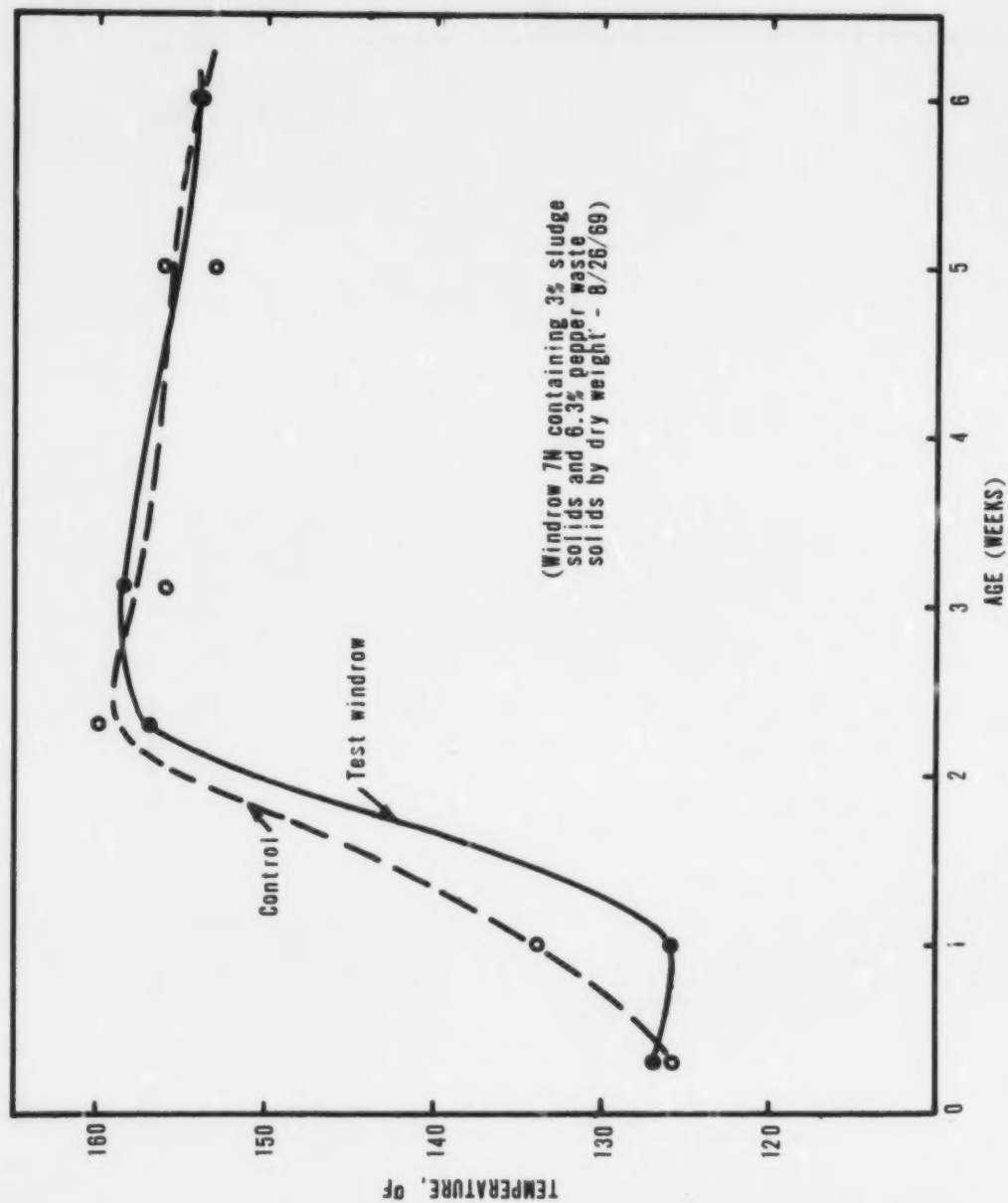


Figure 51. Temperature of sludge-refuse mixture composted with pepper canning wastes.

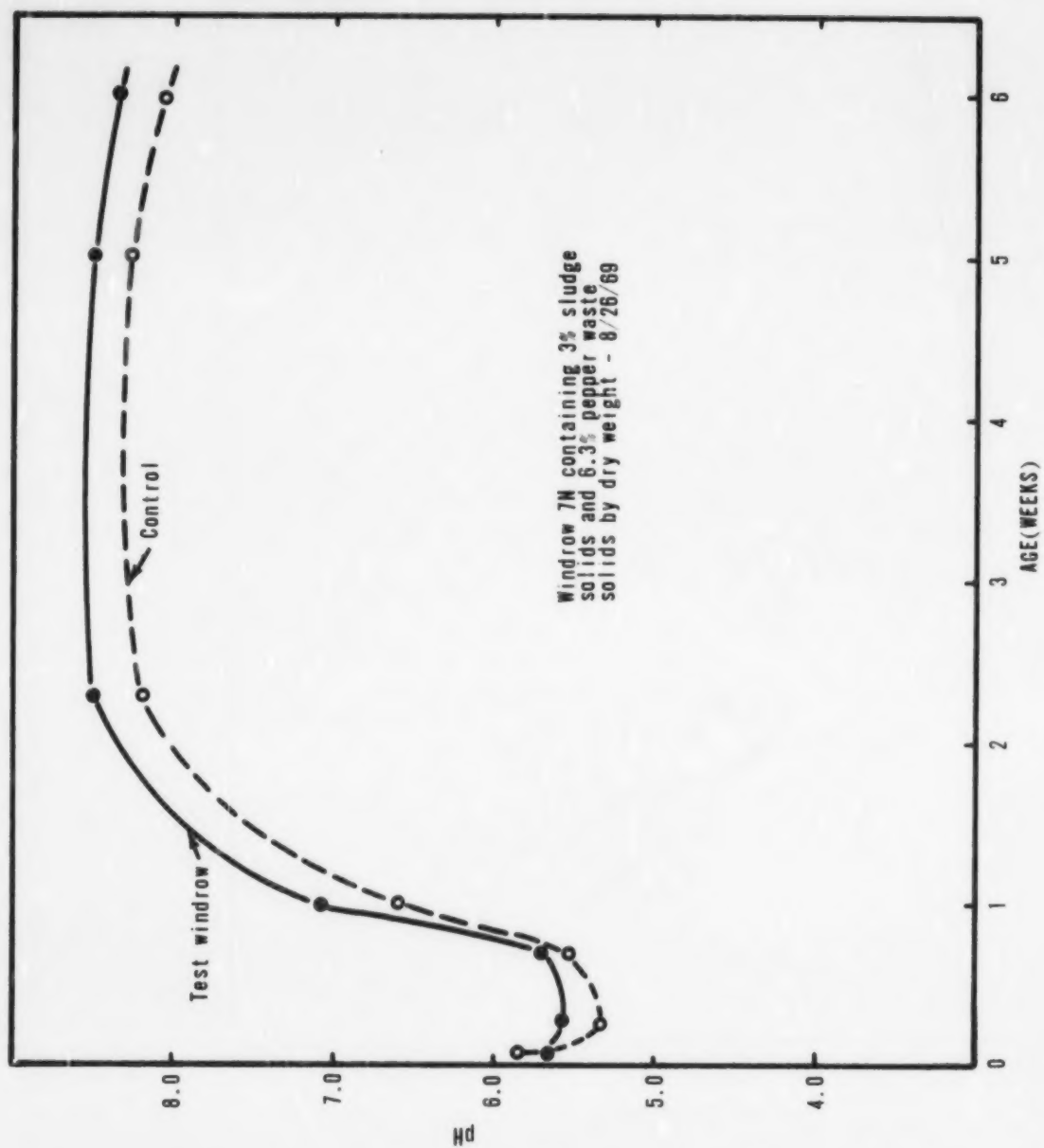


Figure 52. pH of sludge-refuse mixture composted with pepper canning wastes.

Age of windrow in days	Covered		Uncovered	
	Center	At 4" depth	Center	At 4" depth
0	65°	65°	65°	65°
7	116°	114°	144°	139°
14	125°	124°	145°	120°
21	135°	133°	150°	112°
28	137°	134°	149°	131°
35	143°	140°	152°	135°

As can be seen from this tabulation, in the covered portion of the windrow the temperatures in the center of the mass lagged substantially behind those in the uncovered portion. However, after 7 days the surface temperatures were considerably higher in the covered portion due to the greenhouse effect of the plastic. The pH of both parts was about the same. The odors of both parts after turning were about the same, the part under the plastic not being offensive.

The effect of plastic covering for fly control could not be evaluated as the fly population at the composting plant was nil and remained so through the period of the experiment.

Effect of Covering Windrows with Old Compost. In cold weather a retardation of heating has been observed in the windrows. To evaluate the usefulness of covering the new windrows with old compost, three windrows were thus treated.

Windrow 14J was covered with a 12-in. layer of old compost for half its length on zero day. The covered portion showed a steeper rise in temperature at the interface between the old and new than did the control near the surface. It reached 106 F in 3 days, while the control required 4 days to reach this temperature. At 5 days, the control had reached

116 F against the 108 F of the covered portion. On the seventh day, the control was at 112 F and the covered portion at 108 F. Thereafter they both cooled, the control to 107 F and the covered portion to 98 F, by the ninth day, showing need for a turning.

In the center of the mass, windrow 14J reached a higher temperature, 108 F, than the control by the third day. It thereafter became cooler. The center of the control reached a temperature of 110 F in 5 days, 142 F at 9 days, and then began to cool for lack of aeration.

Windrow 16J was covered similarly on the third day. On that day, immediately after covering, the test portion showed 56 F and the control 48 F at the interface and surface, respectively. On the fifth day, the uncovered portion had reached 118 F against the test portion's 103 F. At 10 days, the control was at 102 F against the test portion reading of 104 F.

The center of the mass of uncovered portion of 16J was 13 F lower than that of the test portion on the day they were covered. By the fifth day, the test portion had reached 95 F against the 114 F of the control. By the seventh day, the test portion was only 92 F at its center while the control was at 135 F. Both cooled thereafter for need of a turning.

Windrow 13J was similarly covered on the seventh day. Starting at 4 degrees apart on that day, they both had reached about 120 F on the next day at the interface. From then on, the covered portion showed an increase in temperature at the interface to the fifteenth day, when it was at 131 F. The control showed only 109 F.

In the inner mass, the control steadily rose from 116 F to 151 F on the thirteenth day while the test portion had declined from 114 F to 104 F.

The ambient temperature during this period was about 32 F. All rows were turned before being covered.

It is apparent from these studies that covering windrows at these times has an adverse effect on the temperatures in the center of the windrow, with no significant advantage being gained with surface temperatures. This was observed when they were covered with plastic, and is apparently due to preventing the windrow from "breathing" although the effect of the cover in compacting the underlying refuse may also be a factor. Extrapolating from the results of the windrow covered at 7 days, it appears that the time to cover a windrow to achieve thermal kill at the surface is after it has reached its maximum temperature (2-3 weeks). Such a procedure is under consideration but will require investigation.

pH Observations. Observations of pH changes with age revealed the characteristic curve as shown in Figure 53.

The pH showed an acid condition for the first week generally with some values below 5.0. As the pH rose above 6.0 to a range of 7.5 to 8.0 during the second week, the temperatures also increased. The pH leveled off in a range of 7.8 to 8.5 for the rest of the composting and curing time.

Microbiological and Fly Population Studies

Bacteriological Statistical Experiments. A series of experiments was undertaken by the microbiologist to determine the variability of the bacterial population counts of compost samples due to the inherent heterogeneity of the material itself.

Experiment 1. This experiment was performed to evaluate variation due to error in laboratory procedure. Ten grams of

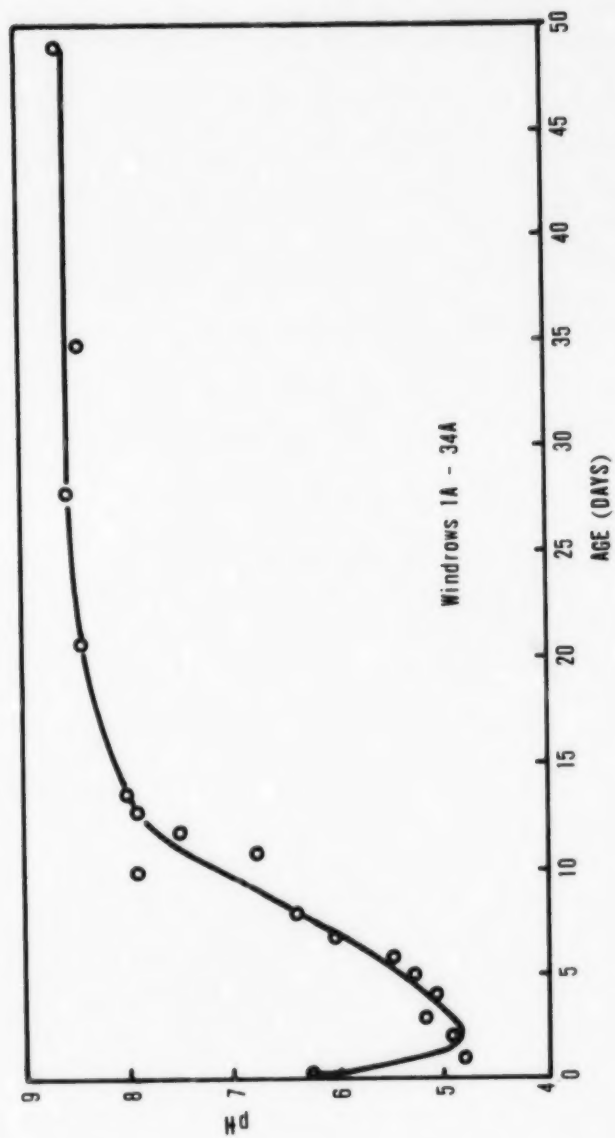


Figure 53. Average pH in windrows 1A thru 34A (1-1/2-ft depth).

zero day compost were homogenized in a 100 milliliter phosphate buffer (pH 7.2). Five 1 milliliter aliquots were removed from this homogenate, each was serially diluted, and the appropriate range of dilutions was incorporated into pour-plates of tryptone glucose extract agar. Plate counts were made at 48 hrs. Results were as follows:

Sample 1	229 x 10 ⁴ cells per ml of homogenate
2	243
3	249
4	248
5	233

average = 240 x 10⁴ cells per ml of homogenate

Since cell distribution should theoretically be Poissonian, the standard deviation should be 15.5×10^2 cells per ml of the average count, if the laboratory technique is adequate. None of the five counts exceeded this range.

Experiment 2. A set of five 10-gram samples was drawn from a zero day windrow; each was homogenized in 200 milliliters of sterile phosphate buffer. Plate counts were made on each of the five homogenates. In addition, the fifth homogenate was plated in triplicate to determine plating variation. A set of five 5-gram samples was drawn from another zero day windrow, homogenized in 100 milliliter aliquots of sterile buffer, and plated as above. Results were:

Sample 1	51 x 10 ⁵	per ml homogenate for the five
2	65	10-gram samples
3	150	
4	137	
5a	105	
5b	126	
5c	122	

Std. deviation = $\pm$ 42 percent for samples 1-5a

Sample 1	66 x 10 ⁶	per ml homogenate for the five
2	49	5-gram samples
3	182	
4	62	
5a	42	
5b	66	
5c	28	

Std. deviation = $\pm$ 73 percent for samples 1-5a

The above experiments were repeated with 49-day compost using the same experimental procedure. The results were as follows:

Sample 1	62 x 10 ⁴	per ml homogenate for the five
2	56	10-gram samples
3	71	
4	33	
5a	93	
5b	80	
5c	81	

Std. deviation = $\pm$ 35 percent for samples 1-5a

Sample 1	52 x 10 ⁵	per ml homogenate for the five
2	32	5-gram samples
3	281	
4	33	
5a	30	
5b	22	
5c	25	

Std. deviation = $\pm$ 140 percent for samples 1-5a

The value of determining the standard deviation in this regard is that the range in which 67 percent of the sample counts should fall is defined. It is clear from the limited data presented here that choosing 10-gram samples would give a more accurate and reproducible estimate of the actual cell counts than the choosing of 5-gram samples. Samples of up to 200 grams were used in the project laboratory at Johnson City.

Survival of *Mycobacterium phlei*. The Staff Microbiologist conducted studies of the survival in composting of *Mycobacterium phlei* Strain 41 obtained from Dr. George Kubica, National Communicable Disease Center, Atlanta, Georgia. This strain, which is rather thermophilic, was used rather than *Mycobacterium tuberculosis*. A non-virulent strain of the latter was concurrently being used in survival studies by another investigator.

During preliminary experiments in the project laboratory, attempts at the isolation of *Mycobacterium phlei* from seeded raw ground refuse samples by classical published methods proved unsuccessful. Therefore, all insertions were of necessity made with cultures grown on Lowenstein-Jensen (L-J) agar slants at 45 C for 3 days. All insertions were prepared in duplicate and inserted on either zero day or day 14 at depths of 2 in., mid-depth, and in the toe of the windrow. At selected time intervals, the duplicate slants were removed from the windrows. Subcultures were made by washing each slant with 0.5 milliliters of sterile phosphate buffer. The buffer-cell suspension was then transferred to a new L-J slant and incubated for at least 10 days at 37 C. Viable cultures would usually produce detectable growth within 3 days. A total of 136 sets of duplicate sample (224 tubes) was inserted into 12 windrows.

Table 11 gives the findings. No samples inserted at mid-depth on zero day or day 1 were found to contain viable cells after 14 days of composting. For the insertions at the depth of 2 in., viable cells were found after 49 days where the temperature reached only 92 F. In other windrows none were found at compost ages over 21 days where temperatures subsequently reached 118 F. Where temperatures reached 128 F or over at the 2-in. depth, no viable cells were found. This condition was usually obtained by the 14th day. For samples inserted in the "toe" of the windrow, viable cells were found to the point at which temperatures reached 134-136 F. In one case, viable cells were found at mid-depth at a temperature of 138 F on the seventh day of composting. Samples retrieved at greater ages were not viable.

From the data obtained in these studies it appears that temperatures as low as 128 F are sufficient to kill *M. phlei* provided the time of exposure is sufficient. Seven days at 128 F should be sufficient with shorter times for temperatures over 130 F. Insertions were made under artificial conditions due to the fact that they were slant cultures and not directly exposed to the compost. Temperature, therefore, was the sole factor in their destruction. Where proper mixing is practiced and temperatures of 140 F or over are obtained, *M. phlei* would be destroyed.

Pathogen Survival Studies under Contract. The intensive studies on the survival of pathogens and parasites in the windrow composting of refuse and sewage sludge were carried out under two contracts (PH-86-67-112 and PH-86-68-143) with East Tennessee State University in the period July 1967 through June 1969.

TABLE 11

MYCOBACTERIUM SURVIVAL IN COMPOST
(Mycobacterium phlei)

Insertions into Windrows 18H (11/19/68) and 28H (12/10/68) on Day 14

Exposure Time (days)	Viable Cells Detected		Temperatures, °F		Insertion Location
	18H	28H	18H	28H	
0	(++)	(++)	120	132	2" and mid-depth
1		(+-)		152	2"
		(--)		162	mid-depth
2		(--)		146	2"
		(--)		160	mid-depth
3	(--)	(--)	128	144	2"
	(--)	(--)	158	152	mid-depth
7	(--)	(--)	148	148	2"
	(--)	(--)	158	156	mid-depth

All samples removed after 14 and 21 days exposure were negative

Insertions into Windrow 21 (12/10/68) on Day 0

Exposure Time (days)	Viable Cells Detected		Temperatures, °F		Insertion Location
0	(++)		34-40		2", mid-depth, and toe area of windrow
3	(++)		46		2"
	(++)		40		mid-depth
	(++)		44		toe area
7	(++)		98		2"
	(++)		78		mid-depth
	(++)		50		toe area
17	(--)		152		2"
	(--)		160		mid-depth
	(+)		126		toe area
21	(--)		142		2"
	(--)		150		mid-depth
	(--)		114		toe area

Insertions removed from all three insertion depths at 35 days
were negative.

TABLE 11 (CONT'D)

Insertions into windrow 191 (1/7/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	38	2", mid-depth, and toe area of windrow
7	(++)	26	2"
	(++)	30	mid-depth
	(++)	46	toe
14	(++)	92	2"
	(++)	108	mid-depth
	(++)	92	toe
21	(++)	102	2"
	(--)	142	mid-depth
	(++)	98	toe
28	(--)	118	2"
	(--)	142	mid-depth
	(--)	116	toe

Insertions into windrow 221 (1/13/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	34	2", and mid-depth
7	(++)	52	2"
	(++)	50	mid-depth
21	(++)	76	2"
	(--)	130	mid-depth
24	(++)	90	2"
	(--)	140	mid-depth
28	(++)	96	2"
	(--)	148	mid-depth
35	(++)	104	2"
	(--)	132	mid-depth
49	(++)	92	2"
	(--)	126	mid-depth

TABLE 11 (CONT'D)

Insertions into windrow 29I (1/22/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	36	2", and mid-depth
7	(++)	102	2"
	(++)	122	mid-depth
14	(++)	88	2"
	(++)	110	mid-depth
28	(--)	144	2"
	(--)	152	mid-depth
35	(--)	122	2"
	(--)	142	mid-depth
49	(--)	110	2"
	(--)	142	mid-depth

Insertions into windrow 24J (3/5/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	62	2", and mid-depth, and toe area of windrow
7	(++)	96	2"
	(+-)	130	mid-depth
	(--)	146	toe
14	(--)	128	2"
	(--)	152	mid-depth
	(--)	134	toe
21			

All samples removed after 21 and 28 days exposure were negative

Insertions into windrow 26J (3/7/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	40	2", mid-depth, and toe area of windrow
7	(++)	122	2"
	(--)	142	mid-depth
	(+-)	110	toe
14	(--)	140	2"
	(--)	150	mid-depth
	(-*)	118	toe

All samples removed after 21 and 28 days exposure were negative

* Insertion culture contaminated

TABLE 11 (CONT'D)

Insertions into windrow 4M (6/30/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	92	2", mid-depth, and toe area of windrow
2	(++)	134	2"
	(++)	120	mid-depth
	(++)	126	toe
7	(--)	134	2"
	(--)	148	mid-depth
	(--)	134	toe
10	(--)	144	2"
	(--)	152	mid-depth
	(--)	136	toe

Insertions into windrow 8M (7/7/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	86	2", mid-depth, and toe area of windrow
2	(++)	118	2"
	(++)	118	mid-depth
	(++)	118	toe
7	(+)	136	2"
	(++)	138	mid-depth
	(+)	134	toe
10	(--)	142	2"
	(--)	146	mid-depth
	(--)	136	toe

* Insertion culture contaminated

TABLE 11 (CONT'D)

Insertions into windrow 17M (7/22/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	88	2", mid-depth, and toe area of windrow
2	(++)	118	2"
	(++)	120	mid-depth
	(++)	116	toe
7	(--)	142	2"
	(--)	142	mid-depth
	(--)	150	toe
10	(--)	120	2"
	(--)	148	mid-depth
	(--)	144	toe

Insertions into windrow 19M (7/24/69) on Day 0

Exposure Time (days)	Viable Cells Detected	Temperatures, °F	Insertion Location
0	(++)	92	2", mid-depth, and toe area of windrow
4	(+-)	142	2"
	(++)	132	mid-depth
	(++)	134	toe
7	(--)	134	2"
	(-*)	146	mid-depth
	(--)	128	toe
10	(--)	140	2"
	(--)	152	mid-depth
	(--)	132	toe

* Insertion sample contaminated

The first contract studied the occurrence and survival of pathogens and parasites. The second covered the actual insertion of organisms with the compost. The findings of the two studies have not yet been published by Dr. William L. Gaby, under whose supervision they were made.

The organisms for which the search for occurrence was made included:

Coliforms

Fecal coliforms

Fecal streptococci

Coagulase positive staphylococci

Salmonella species

Shigella species

Enteroviruses (such as polio)

Pathogenic fungi

Parasitic organisms (protozoa, cestodes, and nematodes)

In this phase, 602 samples were taken from 30 windrows and from the fresh refuse, sewage sludge, and fresh sludge-refuse mix on the days those particular windrows were laid down. The sludge was raw or in a partially digested state. The duration of the composting process at Johnson City is 49 to 56 days, 35 to 42 days of which are on the composting field and the remaining 2 weeks in the curing stage, either in the open or under a shed. Samples were taken from windrows at various intervals during the process and on the terminal day. The samples also were taken from several positions within the windrows.

The studies showed that there was a consistent, inverse relationship between the number of total and fecal coliforms in compost and the windrow

temperature. Temperatures of 120-130 F (49-55 C) were sufficient to reduce coliform populations significantly, often to levels lower than the minimal level of detection by the Most Probable Numbers Method. However, the temperature decrease occurring at the latter stages of the composting process allowed reestablishment of significant numbers (10^2 - 10^5 /g) of coliforms. Fecal streptococci did not appear to be as heat sensitive and maintained populations as high as 10^6 /g even when temperatures reached 130-140 F (55-60 C).

Salmonella species were frequently isolated from the raw sewage sludge; however, no *Salmonella* or *Shigella* species were isolated from samples of windrows over 7 days old. Coagulase positive staphylococci were isolated only from raw refuse, never from sludge, and found in only one windrow on the 49th day. All other samples were negative for coagulase-positive staphylococci after the first day on the field. The studies under the ETSU contract did not give conclusive results for pathogenic fungi. No enteroviruses were ever isolated from sewage sludge, raw refuse, or any compost sample at any time. In the parasite detection studies, 3 percent of the total number of samples (total of 602) of fresh to 49-day compost were positive for one or more parasitic ova or cysts. Of the 49-day samples taken, 8 of 135 (6 percent) were positive for parasites. It is of importance here that these positive findings are based on the identification of parasitic forms which were morphologically intact and not upon actual viability tests.

Organisms used in the insertion studies included:

Bacteria: *Escherichia coli*

Salmonella typhimurium

Salmonella typhimurium

Shigella sonnei

Staphylococcus aureus (coagulase positive)

Parasites: *Endamoeba histolytica*

Ascaris lumbricoides (viable ova)

Endolimax nana

Necator americanus

Fungi: *Histoplasma capsulatum*

Blastomyces dermatitidis

Aspergillus fumigatus

Geotrichum candidum

Viruses: *Polio virus*, Type II

Spirochaetes: *Leptospira philadelphia*

A total of 1,137 samples of bacteria, fungi, parasites, and viruses was inserted in 24 windrows in the second phase. In conformity with the first phase of the work, the samples were planted at various positions within the compost and withdrawn at intervals during the process. Insertions of bacteria were made both in sealed ampules and in such manner that the cultures were in contact with compost. This was done to determine if bacteria could survive the process despite the elevated temperatures and the possible presence of antibiotic substances. Other organisms were inserted in test tubes with screw caps.

In the insertion studies, all bacterial samples in the form of impregnated discs in contact with compost removed after 25 days in the

windrows were rendered nonviable. All samples of *Shigella sonnei* and *Staphylococcus aureus* removed at 14 days and thereafter were nonviable.

Samples of *S. sonnei* inserted in sealed ampules removed after 25 days were nonviable and those of *S. aureus*, similarly prepared, removed after 35 days were destroyed. Only two samples of 18 of *S. aureus* in ampules removed between 25 and 29 days in the compost were positive. One sample of *Salmonella typhimurium* in an ampule was positive after 49 days and showed a reduction of cells from 2×10^8 to 1.6×10^2 . This was a sample inserted and kept in the bottom 6 in. of a windrow where temperatures are lower. On turning, the compost was moved from the bottom but the sample was reinserted in this cooler part of the windrow.

Of the 38 samples of the fungus *Histoplasma capsulatum*, inserted in capped test tubes, three were found to be positive on withdrawal. Withdrawals were made from the seventh day to the 28th day. One positive had been in the compost for 14 days, another 24 days, and the third for 26 days. The 14th and 24th day samples had been kept at the midpoint of the composting mass and the 26th sample in the outer layer at the 2-in. depth.

All samples of the fungus *Blastomyces dermatitidis*, withdrawn at intervals up to the 28th day, were rendered nonviable.

Thermophilic fungi such as *Aspergillus fumigatus* are commonly associated with the composting of various types of solid wastes. On-site observations showed that *A. fumigatus* could be consistently isolated from composting material at Johnson City at all stages of the process. In the insertion studies it survived for 28 days in capped test tubes. Inserted samples of *Geotrichum candidum* survived for 24 days.

All samples of *Endolimax nana* and *Endamoeba histolytica* were destroyed after 8 days' exposure. All samples of *Leptospira philadelphia*, withdrawn at from 2 to 9 days of exposure were deactivated.

Ova of hookworm (*Necatur americanus* or *Ancylostoma duodenale*) disintegrated after 7 days' exposure in the compost.

As with the occurrence studies, the insertion studies show that some morphologically intact parasite forms (*Ascaris*, *Trichuris*, *Necatur*, *Ancylostoma*, and *Hymenolopsis* species) persisted to the end of the composting process. Facilities were not available at ETSU and the Tennessee State Department of Health for a determination of the viability of these parasite forms.

Of the 66 samples of an enterovirus (Polio II) assayed for active virus particles after remaining for various lengths of time in the composting mass, one 3-day and one 14-day sample were found positive. The number of active virus particles recovered from each of the two positive samples amounted to 1 percent of the original concentration inserted. No virus sample was positive after exposure for more than 14 days. The windrow temperatures recorded for the two positive samples at the time they were withdrawn were 133 F (56 C) and 147 F (64 C).

Concurrently with the studies carried on by the Public Health Service and the research done under contract by Gaby of East Tennessee State University, Morgan conducted a study of the survival of *Mycobacterium tuberculosis* in windrows at the Johnson City Plant.⁵ The organism used was an avirulent *M. tuberculosis* var *hominis*, obtained from Trudeau Institute, Inc. The insertion technique was used and the samples were planted in the compost during fall, winter, spring, and summer months. Results revealed

that *M. tuberculosis* was normally destroyed by the 14th day of composting where the average temperature was 149 F (65 C). In all cases the organisms were destroyed by the 21st day. In the study with one windrow, all *M. tuberculosis* organisms were killed by a temperature of 140 F (60 C) or less.

The negative results obtained in the search for pathogenic bacteria (such as *Salmonella*, *Shigella*, and *Staphylococcus*) in compost would indicate that windrow conditions at Johnson City will destroy such pathogens. The results obtained in the pathogen insertion studies, which were supported by the in-house work with *Mycobacterium phlei*, confirm this conclusion.

Of the fungi, *Blasotomyces dermatitidis* samples withdrawn up to the 28th day were rendered nonviable. Although one of the inserted *Histoplasma capsulatum* samples was found to survive 26 days of composting, the search for this fungus in the compost was not successful. *Aspergillus fumigatus*, occasionally pathogenic to humans, could be isolated in the compost itself throughout the process. *Histoplasma capsulatum* has been isolated in garden soils and *Aspergillus fumigatus* is ubiquitous. The literature does not cite any references to fungal infection among sanitation workers in association with the disposal of solid wastes. Present data do not permit any estimate of the possible hazard of pathogenic fungi in this connection and the results at Johnson City do not warrant any restrictions on the use of compost due to these fungi.

Although morphologically intact parasite forms persisted through the process, the data shown by the Belding⁶ show that the ova of *Ascaris lumbricoides*, *Trichuris trichuria*, *Necator americanus*, *Ancylostoma duodenale*,

and *Hymenolopsis diminuta* are killed at time-temperature conditions which are less severe than those which obtain in composting. The work of Scott⁷ in composting bears this out for *Ascaris* ova. It was concluded that the forms found were nonviable although they were not tested with live animals.

Only two of 66 samples of enterovirus (Polio II) were found positive after 14 days in the compost. It is believed that these may have been recontaminated during assay as only very low counts were found and these organisms may be inactivated in 30 min at 122-130 F. No positive samples were found on withdrawal before 14 days.

Evidence from the ETSU studies, the in-house studies at Johnson City, and the work of others in the United States and Europe, indicates that properly processed compost of municipal waste and sewage sludge as used in gardening or agriculture does not constitute a public health hazard. For proper processing, it is imperative that all material in a given windrow be exposed to temperatures in the range of 122-130 F for a period of at least 7 days. To accomplish this the material in the toe area must be picked up and piled on top or at the end of the windrow before turnings. At Johnson City the temperature of each windrow is taken weekly to be sure that the necessary temperatures are reached and held for 7 days. Actually, windrows which have not reached 140 F or over and remained for 7 days, are condemned at Johnson City in order to have a factor of safety.

Cellulolytic Activity in Composting. Cellulases were extracted by homogenizing 200-gram samples of compost in 2 liters of cold phosphate buffer (pH 7.0). The homogenates were clarified by centrifugation, and cellulase activity in the supernatant fluid was determined by measuring the

liberation of reducing sugars (as cellobiose) from acetate-buffered solutions of carboxymethylcellulose. The pH, temperature, ionic strength, and substrate concentration optima were determined for this reaction. The total free cellulase content of compost was measured in relation to the age of the compost to determine the time of maximal production of cellulolytic enzymes. The cellulolytic flora which produce these cellulases in compost were isolated on microcrystalline cellulose-mineral salts agar and identification of these organisms was initiated.

Detectable cellulase activity (as measured by its ability to liberate reducing sugars from carboxymethylcellulose) increased tenfold at a logarithmic rate during the 49-day composting cycle. Concurrently, the cellulose content of the compost decreased from 50 to 30 percent. The pH and temperature optima for the cellulolytic reaction were consistently 6.0 and 149 F (65 C), respectively. Variation of ionic strength between 0.1 and 1.0 had little effect on the velocity of the cellulase reaction. Maximal reaction velocity was achieved with a carboxymethylcellulose concentration of 2.5 percent, a concentration which is near the limit of solubility.

Three species of cellulolytic flora (designated as C-1, C-2, and C-3) were isolated from compost homogenates. C-1 resembled *Aspergillus fumigatus*, grew rapidly at 95-113 F (35-45 C), and caused intense clearing of the cellulose agar within 5 days. C-2, a Gram-variable sporeforming rod, grew rapidly at 95 F (35 C), slowly at 113 F (45 C), and produced diffuse zones of clearing on cellulose agar. C-3 appeared to be a thermophilic actinomycete (rapid growth at 125-131 F); it produced wide zones of cellulose clearing around colonies within 72 hr.

During the 49-day composting process, total cellulolytic activity increased tenfold while the cellulose content of the compost decreased from 50 to 30 percent. Consideration of temperatures which exist in the windrows would indicate that the greatest portion of cellulolytic activity is produced by the thermophilic actinomycete (C-3). This organism, which grows rapidly at 131 F (and has an upper growth limit of 140 F) is the only species isolated which seems compatible with windrow temperatures. This actinomycete might be profitably exploited in various cellulose decomposition or transformation processes. At the present time, studies are being performed to determine production of cellulase in pure culture and the factors which affect this production.

Fly Population Counts. As mentioned in the section on operations, an extensive fly problem developed in the plant area in the summer of 1967. Flies in all stages of their life cycle came to the plant with the refuse being delivered in compaction trailers. Adult flies were widespread over the plant area and were particularly concentrated on windrows just being formed. Table 12 shows the adult fly counts obtained with the Scudder grill from August 31 to September 15, 1967. It will be noted that fresh windrows were the most attractive to the flies. Although many flies came in with the refuse, there was some breeding in the plant at the foot of windrows.

Fly counts were taken in October 1968 to determine the comparative attractiveness of the storage area and several other areas. The storage area contained compost from 42 days old to more than 1 yr old. Table 13 shows findings which indicate that the stored compost had no attractiveness under the conditions which obtained. As would be expected, the greatest number was

TABLE 12

ADULT FLY COUNTS WITH SCUDDER GRILL - 1967

Windrow	8/31	9/1	9/6	9/7	9/8	9/11	9/12	9/13	9/14	9/15
11-13	0	0	-	-	-	-	-	-	-	-
12	1	0	-	-	-	-	-	-	-	-
14-15	0	0	0	-	-	-	-	-	-	-
16-17	0	1	4	-	-	-	-	-	-	-
18-19	10	2	0	1	0	0	2	0	-	-
20-21	3	1	2	2	1	0	3	0	0	-
22-23	3	0	1	1	2	0	0	0	1	1
24-25	3	1	9	3	0	0	5	0	0	0
26-28	2	1	2	1	8	3	5	1	0	0
27	6	11	0	7	3	6	0	2	3	3
29	1	4	5	4	6	3	2	10	4	2
30	2	6	3	3	1	1	3	7	3	2
31	3	-	3	2	-	-	-	-	-	-
32	2	6	4	6	5	1	0	6	1	5
33	5	-	3	1	-	-	-	-	-	-
31-33	-	-	-	-	4	2	3	0	1	1
34	5	6	5	1	2	5	3	3	1	0
35	3	2	5	3	1	0	9	5	4	2
36	6	9	3	1	1	2	1	-	1*	2
37	9	6	0	3	4	3	4	2	8*	10
38	3	1	2	1	4	4	4	1	0	5
39	1	3	5	6	5	4	3	0	2	3
40	1	9	3	4	2	3	2	6	1	0
41	7	2	2	9	11	4	2	5	5	10
42	4	2	15	10	5	6	4	4	8	8
43	0	5	7	9	5	3	1	1	5	7*
44	3	2	8	9	3	2	2	1	4	4
1A	2	3	3	1	3	1	1	4	5	3
2A	6	6	3	2	6	2	5	3	3	7*
3A	-	8	5	4	2	4	1	3	6*	3
4A		7	0	4	1	3	3	2	7	2
5A	Sunny	Cloudy and Windy	2	2	1	5	0	1	0	1
6A			12	2	2	4	3	3	3	5*
7A			120**	3	5	10	4	3	0	2
8A				72**	5	4	0	2	2	0
9A			Sunny and Windy	Partly Cloudy	13**	5	5	4	0	7*
10A					28**	0	5	5	5	8
11A			Sunny and Windy	Partly Cloudy	Partly Cloudy	Partly Cloudy	25**	6	10	0
12A							Clear	15**	4	2
13A								Clear	21**	2
14A							Clear		Clear	10**

* Immediately after turning.

** Windrow formed on this day.

Note: Observations above the upper line within table were made in the drying and curing shed.

TABLE 13
FLY POPULATION DATA

<u>Date</u>	<u>- - - - - Fly Count - - - - -</u>				<u>Time</u>	<u>Wind</u>	<u>Cloud Conditions</u>	<u>Temp.</u>
	<u>Receiving Building</u>	<u>0-day Windrow</u>	<u>35-day Windrow</u>	<u>Storage Area</u>				
10/ 3/68	No reading	26 - 27	7 - 11	0 - 0	2:30 pm	Light	Cloudy	Cool
10/ 4/68	No reading	5 - 7	3 - 1	0 - 0	1:30 pm	Light	Clear	Cold
10/ 7/68	10 - 5	30 - 22	3 - 4	0 - 0	2:45 pm	Light	Partly	Warm
10/ 8/68	4 - 3	7 - 22	2 - 0	0 - 0	1:30 pm	None	Partly	Warm
10/ 9/68	7 - 3	20 - 9	0 - 5	0 - 0	3:30 pm	Light	Partly	Cool
10/10/68	No reading	24 - 17	0 - 3	0 - 0	4:15 pm	None	Cloudy	Cool
10/14/68	11 - 3	26 - 13	3 - 7	0 - 0	3:15 pm	None	Partly	Warm
10/15/68	7 - 20	5 - 30	3 - 3	0 - 0	3:00 pm	Strong	Partly	Warm

Count of flies resting on a Scudder grill in one minute.
Two counts made at each observation point. No distinction
made for species.

found where raw, unground refuse was being handled. The observations were made at the end of the fly season and may not be valid for a period of higher populations. At no time in 1968 or 1969 did the fly population reach a nuisance level at the plant.

Chemical and Physical Characteristics

Sampling Techniques. The chemist completed a series of studies designed to discover a reliable sampling procedure for determination of physical and chemical characteristics of compost.

Forty samples, each of 50 grams, wet weight, were collected from windrow 6H immediately after turning on the 25th day of composting. The windrow was of average cross-section and 120 ft in length. Samples were taken at 6-ft intervals, 20 per side. These were all dried and then ground in a Wiley mill (large pieces of glass, metal, and rock were removed to prevent damage to the mill). The windrow was sampled two additional times on the same day and each set composited. These composited samples were ground wet in a W-W grinder, each was well mixed, quartered, and dried. Randomly selected samples were taken from each quarter of the two samples and ground in the Wiley mill. The 40 individual samples and the four quarters of the two composite samples were then analyzed for nitrogen and ash. Results are summarized in the table below.

	Ash			Nitrogen		
	<u>Avg. %</u>	<u>Std. Dev.</u>	<u>% Dev.</u>	<u>Avg. %</u>	<u>Std. Dev.</u>	<u>% Dev.</u>
40 Individual Samples	19.11	3.46	18.1	.865	.083	9.6
Composite Sample I (8 samples)	26.04	1.61	6.2	.924	.017	1.8
Composite Sample II (8 samples)	25.94	0.66	2.5	1.033	.021	2.0

The lower percentage ash for the 40 individual samples is due to the fact that rocks, glass, etc., were removed prior to analysis.

Windrow 17D was sampled on the 2nd day of composting by taking two large (5,500 grams) composite samples and preparing them in the manner described above (W-W grinder, mixing, drying, Wiley mill). The windrow had not been turned prior to sampling and was at its maximum heterogeneity. Both composites were analyzed for nitrogen, lipids, ash, and pH.

	<u>% Nitrogen</u>	<u>% Lipids</u>	<u>% Ash</u>	<u>pH</u>
Composite I	0.757	5.69	22.7	5.14
Composite II	0.739	5.75	23.5	5.01

From another windrow, 15E, 28 individual samples (about 120 grams apiece) were taken at day 3 before turning. The moisture content of each was determined. The windrow was turned, 30 more samples were taken, and their moisture content determined. Results were:

	<u>% Moisture</u>	<u>Variance</u>	<u>Std. Deviation</u>
Before Turning	57.11	18.98	4.36
After Turning	56.8	5.18	2.28

The two large composite samples taken from 17D before turning were dried and their moisture content determined. Composite I contained 47.3 percent moisture and Composite II 47.1 percent, indicating a satisfactory accuracy of the sampling method. As a consequence, all moisture determinations are now made with a 2,000-4,000 gram composite sample

taken after turning, the whole amount of which is dried for investigative work. For routine work, about 400 grams is taken from this well-mixed sample.

Two conclusions are evident from these data: (1) samples for chemical analysis should derive from a large composite that has been ground and mixed, and (2) sampling should be done, whenever possible, after turning.

Fifty temperature readings were taken on three different windrows at 18 in. Their ages were 8, 22, and 32 days. Results were:

<u>Age of Windrow</u>	<u>Avg. Temperature</u>	<u>Std. Deviation</u>	<u>Variance</u>
8 days	134 F	6.75	45.40
22 days	160 F	5.48	30.00
32 days	161 F	3.94	15.27

These data indicate increasing homogeneous composition as the age of the windrow increases. This can be ascribed to (1) decomposition by the microorganisms, (2) periodic mixing by the windrow turner, and (3) particle size reduction.

It can be seen that for consistent precision more measurements must be taken when working with windrows in the beginning of the composting cycle.

Moisture Content of Raw Refuse. With improved methods of sampling for moisture determinations, the dry weights of a number of windrows (11) were determined in the course of the work on the weight and volume losses. Knowing the weights of the same material as received from the city, the moisture content of raw refuse was determined. The moisture content by wet weight as received ranged from 22 percent to 61 percent over the

period August 8 to December 6, 1968, with an average of 39 percent. This is in the neighborhood of the 35 percent which has been quoted on occasion.

Weight and Volume Losses in Composting. As previously mentioned, from 20 to 30 percent (by wet weight) of the incoming refuse is not compostable and is removed for burial in a landfill. Grinding then reduces the volume of the refuse retained for processing. As digestion proceeds, a weight loss in the form of the two principal products of decomposition, carbon dioxide and water, occurs. This amounts to between 20 and 30 percent of dry weight.

A study of seven batches (windrows) of refuse through the 42-day composting process at Johnson City showed the following relationship of incoming weights and volumes to those of the compost. In this study the amount of noncompostables was somewhat higher than the average of 26 percent observed at this plant.

	<u>Refuse, as Received in Compaction Trailer</u>	<u>Noncompost- ables, Un- compacted</u>	<u>Picked, Ground Refuse, with Water Added</u>	<u>Compost in Windrow at End of Process</u>
Wet weight, tons	100	28.8	111.7	50.4
Volume, cu yd	433	168.4	236.5	172.6
Moisture, percent by wet weight	39	39	60	30
Density, lb per cu yd at given moisture content	463	342	945	584
Density, expressed as the dry weight in lb per cu yd	282	209	378	409

This study shows a compost yield of 50.4 percent by wet weight and 40 percent by volume. It is assumed that the compost will go down on the field at the desired 60 percent moisture and that the finished compost will be dried to 30 percent moisture.

Elemental Composition of Compost. Analyses for certain elements were performed on samples of compost 42 days old or older. Wilson's methods for the gravimetric determination of carbon and hydrogen in solid wastes are given in Reference 8. Additional methods are available in Appendix I. Table 14 shows the average values found, on a dry weight basis. Table 15 gives the results for individual analyses made for six important elements.

Nitrogen in fresh ground refuse ranged from 0.58 to 1.01 percent by dry weight, averaging 0.85 percent. Carbon ranged from 34.4 to 43.6 percent of dry weight, averaging 39.8. For compost 42 days old or older, the nitrogen content was found to be between 0.85 and 1.07 percent of dry weight, averaging 0.93 percent. Table 16 shows the nitrogen content of some organic materials and soil for comparison with that of finished compost.

Analyses for Carbon/Nitrogen Ratios. A total of 37 windrows of different ages (0-130 days) was sampled and analyzed for carbon and nitrogen. The carbon analyses were made in the Research Services Laboratory of the Division of Research and Development, Bureau of Solid Waste Management, in Cincinnati. The nitrogen determinations were performed in the project laboratory.

Figure 54 shows the average carbon to nitrogen (C/N) ratios of composting refuse containing 3 to 5 percent sludge by dry weight for

TABLE 14

ELEMENTS IN FINISHED COMPOST

Johnson City

1968

Percent Dry Weight

<u>Element</u>	<u>Average</u>	<u>Range</u>
Carbon	33.01	26.23 - 37.53
Nitrogen	0.93	0.85 - 1.07
Potassium	0.30	0.25 - 0.40
Sodium	0.42	0.36 - 0.51
Calcium	1.55	0.75 - 3.11
Phosphorous	0.26	0.20 - 0.34
Magnesium	1.61	0.83 - 2.52
Iron	1.18	0.55 - 1.68
Aluminum	0.94	0.32 - 2.67
Copper	less than 0.05	--
Manganese	less than 0.05	--
Nickel	less than 0.01	--
Zinc	less than 0.005	--
Boron	less than 0.0005	--
Mercury	not detected *	--
Lead	not detected *	--

* Lower limits of detection: Mercury, 0.005 percent; lead, 0.05 percent. Neither was found above these levels in any samples tested.

TABLE 15

CONCENTRATION OF CERTAIN TRACE ELEMENTS IN SCREENED COMPOST
(Values expressed as percentage of dry weight unless otherwise noted)

Windrow and age	Iron	Boron	Sodium	Potassium	Phosphorous	Calcium
17D - 42 day*		<2ppm	0.50	0.30		0.75
17D - 49 day*	1.38		0.40	0.29	0.22	1.12
5E - 42 day†	1.19		0.42	0.28		0.92
2E - 42 day‡	0.89	<2ppm	0.36	0.25	0.20	2.46
5E - 42 day§	1.07	<1ppm	0.43	0.25		1.89
Stockpile 1						
- 56 day¶	0.97		0.51	0.33	0.29	1.85
22-23E - 77 day‡	1.24	<2ppm	0.43	0.29	0.25	1.40
22-23E - 130 day‡					0.34	
Stockpile 2						
8G - 36 day¶	1.35	<1ppm			0.27	2.39
with NH_4NO_3 added					0.23	
5E - 154 day†	1.68	<1ppm	0.39	0.29	0.29	3.11
24-25E - 130 day§	1.47	<1ppm	0.43	0.32	0.24	2.29
8G - 42 day§	0.55		0.36	0.40	0.28	1.13

* Contained sewage sludge in an undetermined amount.

† Contained 12 percent sewage sludge solids.

‡ Contained 2 to 5 percent sewage sludge solids.

§ This portion of 5E contained 2 to 5 percent sewage sludge solids.

¶ Contained sewage sludge solids.

TABLE 16

NITROGEN CONTENT OF SOME ORGANIC MATERIALS AND SOIL

	<u>% Nitrogen (dry weight basis)</u>
(1) Finished Compost	0.93
(2) Sewage Sludge (raw)	2.58
(3) Chicken manure	2.61, 2.40
(4) Cow manure	3.42
(5) Peat moss	1.91
(6) Leaves (hardwood)	1.34
(7) Pepper canning wastes	2.82
(8) Tobacco stalks	1.41
(9) Soil	0.1 - 0.3 (approximately)

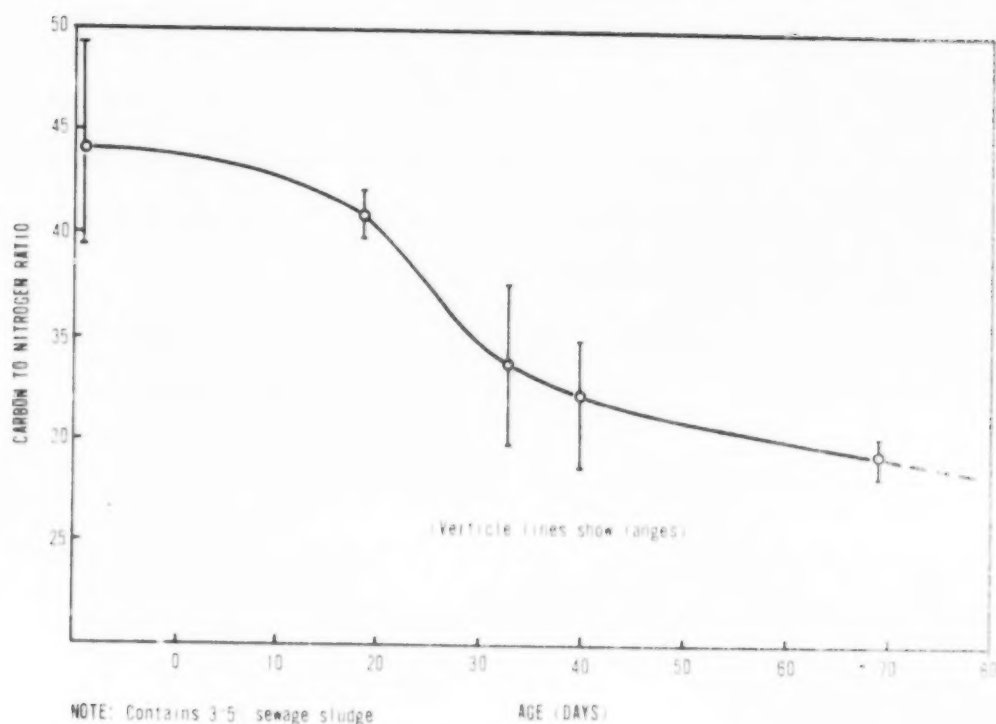


Figure 54. Average carbon to nitrogen ratio of 24 windrows containing 3-5 percent sewage sludge.

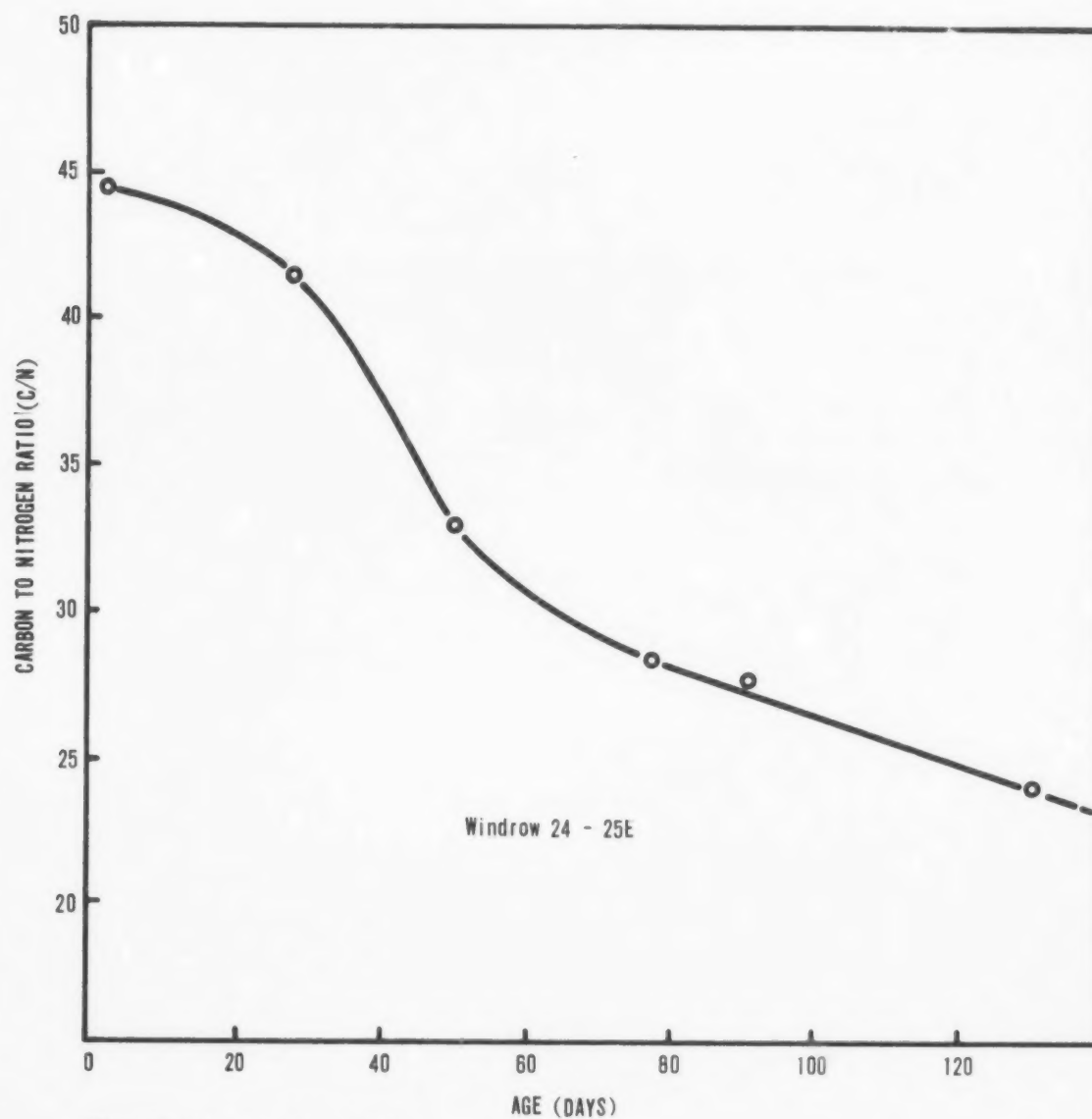
various ages. Ranges are shown but the data, taken from 24 windrows, does not represent a follow-through of all these windrows from 0 to 80 days. The initial C/N ratios of a group of seven windrows showed an average of 44.4. At 42 days of composting a similar group of five windrows showed an average C/N of 33.9 and at 49 days two of these showed an average of 31.9.

Figure 55 shows the decrease of the C/N ratios with age in a windrow especially sampled for this purpose. This windrow did not contain sludge solids. The initial C/N was 44.4 and at 49 days the ratio was 33.0. The similarity of Figures 54 and 55 will be noted.

The C/N ratios at the beginning and end of the composting on the field were determined for several windrows containing additives (Table 17). Windrows to which were added paunch manure and poultry manure showed lower initial C/N ratios. The decreases in the ratios while composting, however, were not as great as in normal windrows. The 42-day ratios were 28.8 for the material containing paunch manure and 24 for the chicken manure-refuse mixture.

The C/N ratios for two windrows to which urea-ammonium nitrate was added showed an increase rather than a decrease after composting. The rise was due to the loss of nitrogen as ammonia as a result of mass action from (1) the increase of pH in the system caused by the addition of Urea- NH_4NO_3 , and (2) shifting of the equilibrium $\text{NH}_4^+ + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} + \text{NH}_3\uparrow$ to the right due to an increase of NH_4^+ and OH^- ions.

Analyses for Chemical Oxygen Demand. A total of 22 samples of compost of different ages (0-168 days) was analyzed for chemical oxygen demand (COD). The results showed a steady reduction with age



NOTE: Contains no sewage sludge.

Figure 55. Carbon to nitrogen ratio of a windrow without sewage sludge.

TABLE 17

CARBON/NITROGEN RATIOS OF COMPOST CONTAINING ADDITIVES

<u>Windrow and Age</u>	<u>Additive</u>	<u>C/N Ratio</u>
13G - 1 day	Paunch manure	31.2
42 days		28.5
19G - 1 day	Chicken manure	25.8
42 days		24.0
8G - 1 day	Urea-ammonium nitrate	9.8
42 days		12.9
17G - 1 day	Urea-ammonium nitrate	17.7
42 days		22.4
1H - 43 days	Urea-ammonium nitrate	29.6
56 days		22.8
30G - 54 days	Animal blood	22.5
33G - 51 days	Pepper canning waste	26.5

from about 900 milligrams per gram for fresh refuse to about 750 milligrams per gram at 56 days of age. A sample taken from compost 168 days old showed a COD of about 300 milligrams per gram. The COD can be used as a gauge of the degree of decomposition of refuse (Figure 56).

Cellulose, Starch, and Sugar Content. The average cellulose content of refuse at Johnson City was found to be 49 percent on a dry weight basis. After composting for 28 days, it was 43 percent and at 49 days the content was 31 percent.

The average initial starch content was 4.0 percent and dropped to less than 1.0 percent after 28 days of composting.

The average sugar content at the start of composting was 0.8 percent and dropped to less than 0.1 percent within 14 days.

Figure 57 illustrates the diminishing content of these constituents of refuse and compost with age.

Calorific Value of Refuse and Compost. At Johnson City, the calorific values for composite samples of composting refuse containing 3 to 5 percent sludge solids were found to be initially 4,077 calories per gram, diminishing to 3,669 on the 49th day of composting and to 2,947 calories per gram for compost 1 year old.

Cost Studies

A system of cost accounting for plant operations and maintenance was developed to provide accurate cost data for each phase of plant operation for appraisal of windrow composting as a method of solid waste management. Plant operations and activities were divided into various categories or

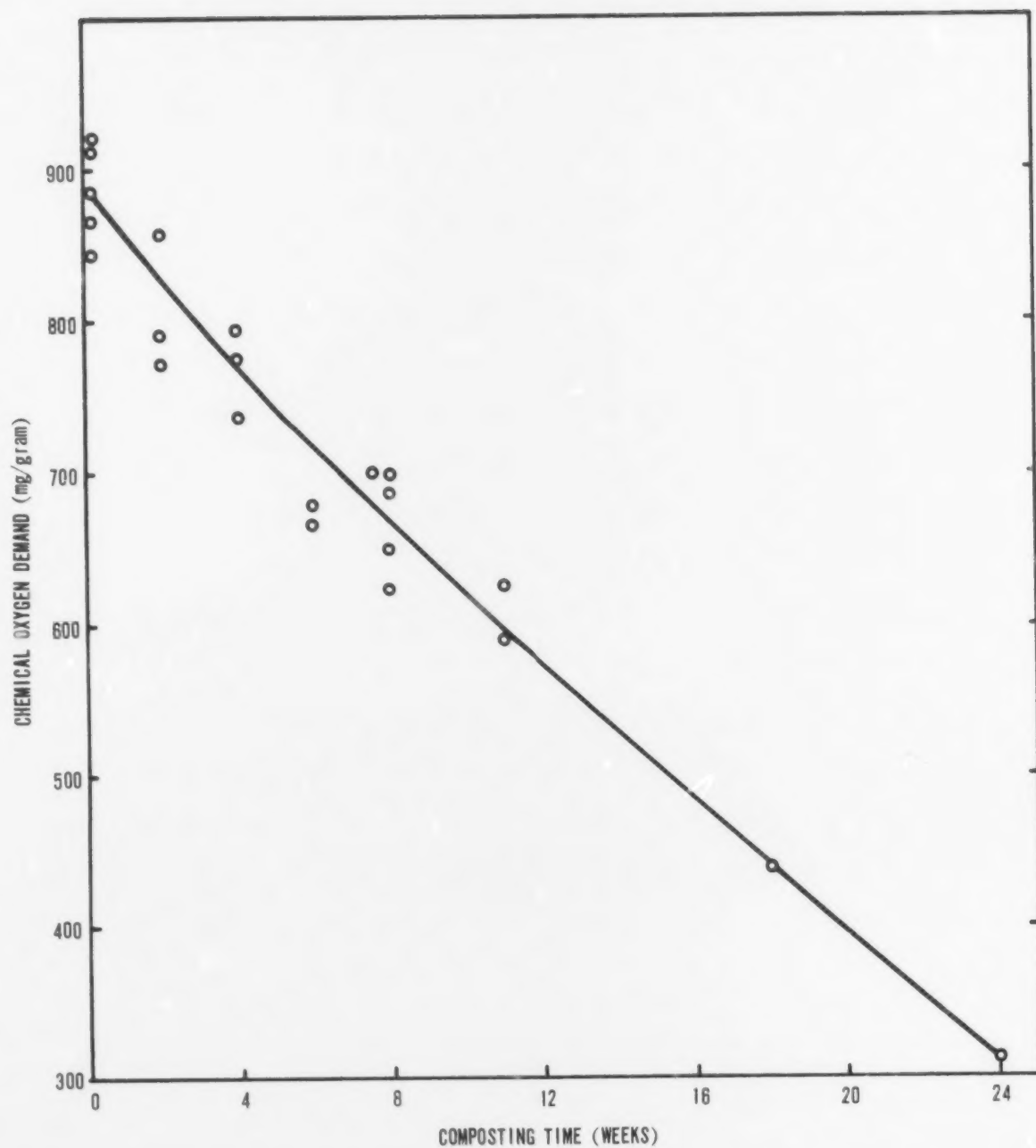
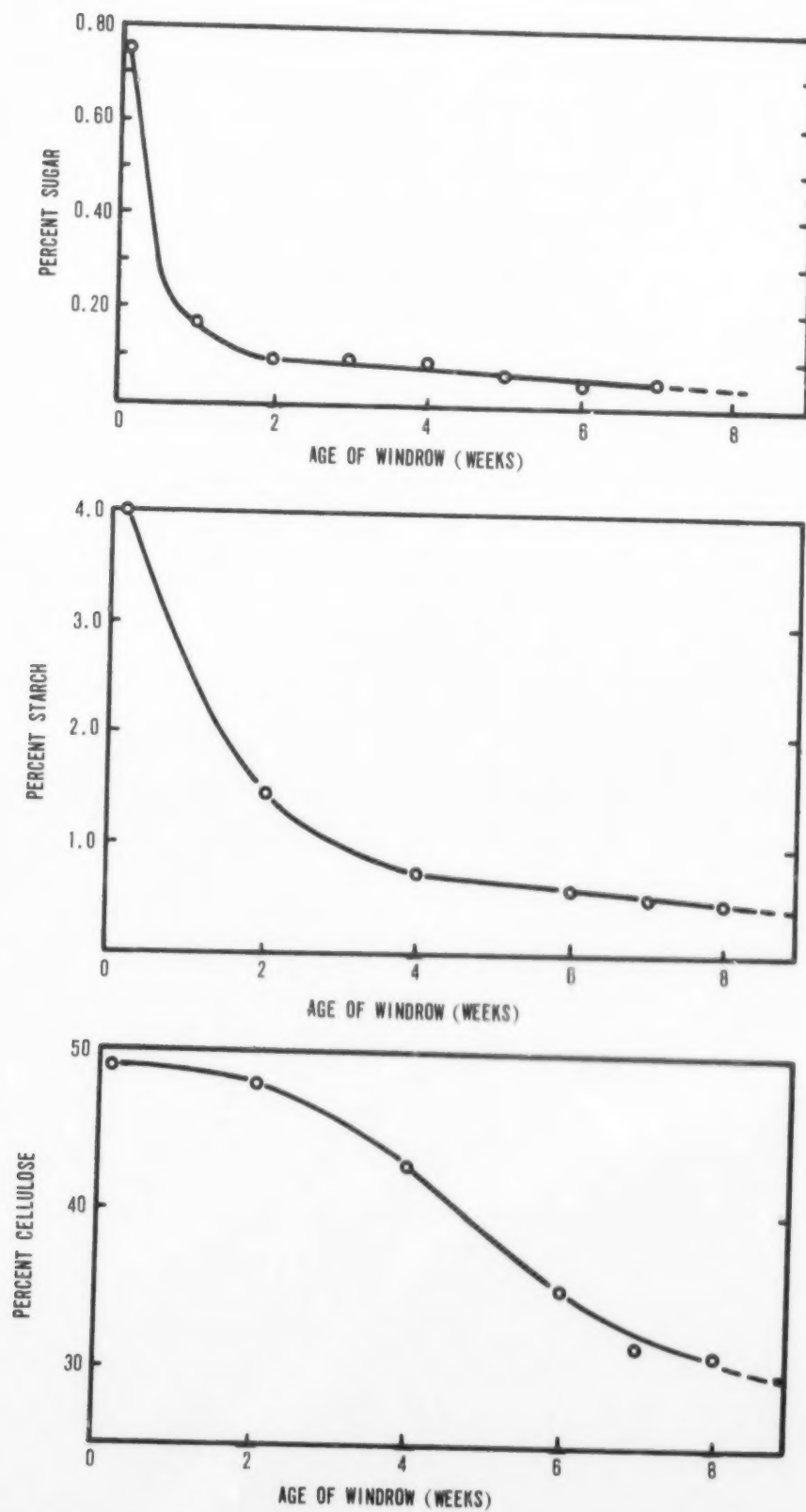


Figure 56. Chemical oxygen demand of composting refuse.

Figure 57. Sugar, starch, and cellulose content of composting refuse.



units with an account number for each. Cost data used to report the project costs and provide the basis for projections to other windrow plants were obtained from these monthly, quarterly, and year-end financial statements of operations (Appendix II).

Capital Cost. The total construction cost for the plant, including the modifications made since startup, is \$958,375. Table 18 itemizes these costs. On the basis of per ton daily capacity the actual capital investment costs* were \$18,580. On a per-ton-refuse processed basis, the capital investment cost is \$12.98 (at 34 tons per day in 1968) (Table 19).

The average rate at which the refuse has been received at the plant would permit the processing of 52 tons in a normal processing day (6-1/2 hr for processing and 1-1/2 hr for cleaning operations). Projecting the actual costs to the 52 tons per day basis, the capital investment cost would be \$6.88 per-ton-refuse processed (Table 19).

Operating Cost. Actual costs for operating the composting plant in 1968 were \$18.45 per-ton-refuse processed (Table 20). The nature of the operations (research and development) and the inability of the Johnson City municipality to deliver enough refuse for operation at full capacity are some reasons for this high unit cost. A cost of \$13.40 per-ton-refuse processed was projected for operating this plant at 52 tons per day (Table 21). Some modifications were made for the research work being conducted.

*Capital cost calculations assumed straight line depreciation over 20 years of buildings and equipment (excluding land) and bank financing at 7-1/2 percent over 20 years.

TABLE 18

CONSTRUCTION COSTS FOR THE USPHS-TVA
WINDROW COMPOSTING PLANT (52-Ton Per Day) ^{1/}

	Construction or Installation	Equipment and/or Materials	Engineering Design	Total
Site improvements	\$ 78,059.88 ^{2/}		\$ 10,032.00	\$ 88,091.88
Buildings				
Receiving building	90,381.82 ^{2/}		13,982.00	104,363.82
Process building	142,742.36 ^{2/}		21,800.00	164,542.36
Office and laboratory	40,245.28 ^{2/}		7,883.00	48,128.28
Curing and drying shed	44,192.55 ^{2/}		7,111.00	51,303.55
Receiving machinery and equipment				
Hopper conveyor and leveling gate	12,643.94	\$ 24,865.72	5,800.00	43,309.66
Scale	8,058.67	4,266.00	1,112.00	13,436.67
Processing				
Elevating conveyor (sorting belt), w/magnetic separator	23,608.17 ^{2/}	11,667.00	6,828.00	42,103.17
Reject hopper	7,118.70 ^{2/}		965.00	8,083.70
Raspings machine (grinder)	7,477.38	51,160.00	9,380.00	68,017.38
Hammermill (grinder) ^{3/}	2,086.63	9,262.00	1,880.00	13,228.63
Chuting	8,152.52	1,838.19	1,570.00	11,560.71
Conveyors	7,851.69	5,801.00	2,418.00	16,070.69
Sludge filter and appurtenances, including sludge holding tank	2,299.67 ^{2/}	23,273.10	4,320.00	29,892.77
Ground refuse-sludge mixer	3,029.34	6,527.77	1,490.00	11,047.11
Sludge piping	13,760.08 ^{2/}	2,698.65	2,700.00	19,158.73
Power and control system	36,181.73 ^{2/}		5,820.00	42,001.73
Bucket elevator	1,408.77 ^{2/}	6,000.00	1,282.00	8,690.77
Loading bin and chute	11,602.99 ^{2/}		1,324.00	12,926.99
Composting field, site preparation and waterlines	28,792.61 ^{2/}		9,901.00	38,693.61
Regrinding and screening	47,500.00 ^{4/}			61,189.65
Gasoline dispensing installation	1,754.62	13,689.65	253.00	2,795.62
Mobile equipment, including front end loaders and turner		788.00		48,789.48
Tools, small equipment, etc.		6,738.74		6,738.74
Office and laboratory equipment ^{5/}		4,210.00		4,210.00
Estimated cost of site (9.5 acres)	\$618,949.40	\$221,575.30	\$117,851.00	\$958,375.70
				\$965,975.70

1. Based on one shift per day, 6½ hours of processing and 1½ hours for cleanup.
2. Contains all or part of required materials.
3. This mill is being replaced.
4. Includes installation, construction materials, and design costs.
5. Laboratory costs include only that for sample process control equipment.

TABLE 19
YEARLY INVESTMENT COSTS FOR THE USPHS-TVA
WINDROW COMPOSTING PLANT

Item of Cost	Cost (\$)*
Construction	958,375
Land costs	7,600
Total	965,975
Depreciation/year†	47,920
Interest/year ‡	45,080
Cost per ton daily capacity	18,580
Cost per ton refuse processed	12.98 (6.88)§

* Actual costs of plant as built at Johnson City. Plant operates on 1 shift day. Cost per ton based on 1968 level of 7,164 tons of refuse processed.

† Straight line depreciation over 20 years of buildings and equipment, excluding land.

‡ Bank financing at 7 1/2 percent over 20 years. Yearly figure is average of 20-year total interest charge. Land cost included.

§ Cost of Johnson City plant adjusted to design capacity of 13,520 tons refuse processed per year.

TABLE 20

ACTUAL COST OF OPERATIONS FOR THE USFIS-TVA COMPOSTING PLANT (1968) ^{1/}
(7,164 tons processed in 210 days)

	OPERATIONS					MAINTENANCE				
	Salaries and Benefits	Super-vision	Electric power	Utilities (excluding electricity)	Truck Use	Supplies and Materials	Miscellaneous	Salaries and Benefits	Super-vision	Miscellaneous
Receiving ^{1/}	\$ 6,905	\$ 1,181	\$ 59	\$	\$	\$ 28	\$	\$ 974	\$ 250	\$
Picking and sorting	8,116	1,388	17			319		305	78	
Disposal of rejects ^{2/}	7,351	1,258			3,524	38		620	159	
Grinding (rasper)	3,211	549	770					2,134	548	
(hammermill)	39	7	17					231	59	
Composting										
Hauling and handling	5,930	1,015	28		5,764	327	50	3,073	789	
Turning and wetting	4,615	790				291	21	2,342	600	
Curing	982	168			224	9		45	12	
Storage	2,477	424			577		48			
Operation and maintenance										
Grounds, buildings, and utilities			1,165					4,506	1,156	
Cleanup of process and receiving buildings	9,556	1,635				123				
Office and laboratory	6,123	1,048	378	614		800	144			
Other	1,712	293		134	1,044	4,519	624			
Regrinding and screening	4,293	734	130		1,230			846	217	
Sewage sludge processing	3,350	573	54			782		2,970	762	
	\$64,660	\$11,063	\$2,618	\$748	\$12,363	\$7,236	\$887	\$18,046	\$4,630	\$477
								\$7,801		\$32,590
										\$132,165

1. At plant site.

2. Includes cost of haulage to landfill (no landfilling costs).

TABLE 21
ACTUAL ANNUAL COSTS OF
OPERATING THE USFHS-TVA PLANT
PROJECTED TO FULL CAPACITY (1968) ^{1/}

	OPERATIONS					MAINTENANCE				
	Salaries & Benefits	Electric Power	Truck Use	Supplies & Materials	Miscel- laneous	Total	Salaries & Benefits	Supplies Materials	Repairs	Total
Receiving ^{2/}	\$ 11,400	\$ 145	\$	\$ 50	\$	\$ 11,595	\$ 1,550	\$ 500	\$ 500	\$ 2,550
Picking & Sorting	17,200	40		500		17,740	900	100		1,000
Disposal of Rejects ^{3/}	9,650		2,768	70		12,488	750	75		825
Grinding (rasper)	4,550	1,530		100		6,180	4,750	5,000		9,750
Composting	18,150	55	5,000	1,090	75	24,370	8,200	1,600	950	10,750
Curing	1,750		536	50		2,336			25	25
Storage	5,200		1,384	50	50	6,684				
Operation & Maintenance of Grounds, Buildings, & Utilities		1,430			200	1,630	6,000	650		6,650
Cleanup of Process & Receiving Buildings	11,550			150		11,700				
Office & Laboratory ^{4/}	7,250	465		800	800	9,315				
Other				5,000	1,000	6,000				
Regrinding & Screening	8,150	870	1,384	500		10,904	2,900	300	200	3,400
Sewage Sludge Processing	7,200	140		2,935		10,275	2,350	1,250	250	3,850
	102,050	4,675	11,072	11,295	2,125	131,217	27,400	9,475	1,925	38,800
Administrative & Overhead	8,600					8,600	2,400			2,400
	\$110,650	\$4,675	\$11,072	\$11,295	\$2,125	\$139,817	\$29,800	\$9,475	\$1,925	\$41,200
										\$181,017

1. Production of 13,520 tons, based on 260 working days in year.

2. At plant site.

3. Includes cost of haulage to landfill but no landfilling costs.

4. Operations only. Does not include maintenance of building, etc.

Table 22 summarizes the actual capital and 1968 operating costs for the plant.

The construction cost of \$958,375 for the plant is subject to some qualifications. A high proportion (38 percent of plant cost) is in buildings, partly because of the multi-story design, with equipment installed on the second and third floor levels. More ground level floor space and simpler framing, as used in common mill buildings, with installation of equipment independently of the structure, would have permitted less expensive construction. A case in point is the 150-ton-per-day plant at Gainesville, Florida, where the cost of the buildings, estimated at \$150,000, is approximately 11 percent of the total plant investment.

Labor Cost. With respect to the plant operating costs in 1968, labor constituted about 75 percent of this cost. Based on 50 tons of refuse processed per day, 1969 labor costs amounted to 78 percent of operating expenses. Table 23 provides salary information of the TVA working complement as of January 1, 1969.

Cost Data Projected to Other Plants. Estimates of the capital, investment, and operating costs for various capacity windrow composting plants were developed based on the actual costs recorded during the report period at the USPHS-TVA plant (Tables 24, 25, and 26). The projections indicate that the total yearly costs for various size windrow composting plants will range from \$19.77 per-ton-refuse processed for a 50-ton-per-day plant to \$10.71 per-ton-refuse processed for a 200-ton-per-day plant on two shifts (Table 27).

TABLE 22

SUMMARY OF PROCESSING COSTS FOR THE USPHS-TVA COMPOSTING PLANT
JOHNSON CITY, TENNESSEE *

Tons per day	Capital cost- per-ton daily capacity	Cost per ton refuse processed		
		Capital	Operating	Total
34 (7,164 tons/year) **	\$18,580	\$12.98	\$18.45	\$31.43
52 (13,520 tons/year) ***	18,580	6.88	13.40	20.28

* Based on actual costs of Johnson City composting plant with 7½ percent bank financing over 20 years. Equipment and buildings depreciated over 20 years (straight line). Operating costs based on actual costs for calendar year 1968.

** Actual processing for 1968 operations.

*** Operations projected to full capacity.

TABLE 23

SALARIES OF TVA PERSONNEL
PHS-TVA Composting Project
January 1, 1969

	<u>ANNUAL SALARY</u>
Foreman	\$9300
Asst. Foreman	7740
Equipment Operator (2)	7050
Truck Driver (3)	6885
Maintenance Mechanic (2)	8490
Laborer (4)	6100

The salaries shown are for an 8-hour day, with 8 paid holidays, and 20 paid vacation days. Added benefits amount to 16.75 percent of the salaries, not including leave benefits. Overtime is paid at the rate of time and one-half on regular workdays and double time on holidays.

TABLE 24

ESTIMATED CAPITAL COSTS FOR WINDROW COMPOSTING PLANTS

Item of cost	Daily plant capacity in tons per day (T/D)					
	52 T/D (Johnson City Plant - 1 shift) ^{1/}	50 T/D (1 shift) ^{2/}	100 T/D (50 T/D 2 shifts) ^{3/}	100 T/D (1 shift) ^{3/}	200 T/D (100 T/D 2 shifts) ^{3/}	
Buildings	\$368,335	\$210,000	\$231,000	\$ 231,000	\$ 251,000	
Equipment	463,250	482,700	482,700	607,100	607,100	
Site improvement ^{4/}	126,790	126,800	126,800	152,000	152,000	
Land cost ^{5/}	7,600	8,400	12,400	12,400	21,200	
Total cost	\$965,975	\$827,900	\$852,900	\$1,002,500	\$1,031,300	
Total cost per ton daily capacity	\$ 18,580	\$ 16,560	\$ 8,530	\$ 10,020	\$ 5,460	

1. Actual cost of the research and development PHS-TVA Composting Plant at Johnson City, Tennessee.

2. Based on Johnson City cost data adjusted for building and equipment modifications.

3. Estimates based on actual Johnson City cost data projected to the larger daily capacity plants. (See Tables 28 through 33).

4. Includes preparation of composting field with crushed stone and needed utility lines.

5. Land cost are estimated based on approximate land values near Johnson City, Tennessee, of \$800 per acre.

TABLE 25

ESTIMATED INVESTMENT COSTS FOR WINDROW COMPOSTING PLANTS (1969)

Item of cost	Plant capacity in tons per day (T/D)					
	52 T/D (Johnson City, 1 shift, 7,164 tons, 1968)	50 T/D (1 shift, 13,000 T/year)	100 T/D (2 shifts, 26,000 T/year)	100 T/D (1 shift, 26,000 T/year)	100 T/D (1 shift, 26,000 T/year)	200 T/D (2 shifts, 52,000 T/year)
Construction	\$958,380	\$819,500	\$840,500	\$989,100		\$1,071,100
Land costs	7,600	8,400	12,400	12,400		21,200
Total	\$965,980	\$827,900	\$852,900	\$1,001,500		\$1,092,300
Depreciation/year ^{3/}	\$47,920	\$41,000	\$42,000	\$49,500		\$53,550
Interest/year ^{4/}	\$45,080	\$38,600	\$39,800	\$46,200		\$51,000
Cost per ton daily capacity	\$18,580	\$15,560	\$ 8,530	\$10,020		\$ 5,460
Cost per ton refuse processed	\$12.98 (6.88) ^{5/}	\$ 6.12 (5.38) ^{6/}	\$ 3.15 (2.76) ^{6/}	\$ 3.68 (3.28) ^{6/}		\$ 2.01 (1.73) ^{6/}

1. Actual costs of plant as built at Johnson City. Plant operates on 1 shift day. Cost per ton based on 1968 level of 7,164 tons of refuse processed.
2. Based on Johnson City plant cost data adjusted for less elaborate equipment, buildings, and modifications.
3. Straight line depreciation over 20 years of buildings and equipment, excluding land.
4. Bank financing at 7½ percent over 20 years. Yearly figure is average of 20-year total interest charge. Land cost included.
5. Cost of Johnson City plant adjusted to design capacity of 13,520 tons refuse processed per year.
6. Estimated cost without sludge processing equipment.

TABLE 26

ESTIMATED YEARLY OPERATING COSTS FOR VARIOUS CAPACITY WINDROW COMPOSTING PLANTS

Plant capacity (tons of refuse processed/ day) (T/D)	Number of shifts	Plant operating costs (\$)		Operating costs per ton refuse processed (\$/ton)
		Operations	Maintenance Total	
52 T/D 1968 Johnson City (7,164) *	1	\$99,575 ** (139,817)	\$32,590 ** (41,200)	\$18.45 ** (13.40)
50 T/D *** (13,000)	1	133,950	43,700	13.65
100 T/D *** (26,000)	2	213,795	59,150	10.50
100 T/D *** (26,000)	1	197,850	59,850	9.90
200 T/D *** (52,000)	2	357,015	95,400	8.70

* Figure in parentheses is total tons of raw refuse processed in 260-day work year.

** Costs projected for operating PHS-TVA composting plant at design capacity of 52 tons per day (13,520 T/year) in 1969.

*** Estimated costs based on PHS-TVA composting project operating cost data.

TABLE 27

SUMMARY OF ESTIMATED CAPITAL, OPERATING AND TOTAL COSTS
FOR VARIOUS SIZE WINDROW COMPOSTING PLANTS ^{1/}

Plant Capacity tons/day (tons/year)	Number of Shifts	Capital cost ^{2/} (per ton/day)	Unit cost per ton refuse processed		
			Capital & Investment	Operating ^{3/}	Total
52 ^{4/} (13,520)	1	\$18,580	\$6.88	\$13.40	\$20.28
50 (13,000)	1	\$16,560	\$6.12	\$13.65	\$19.77
100 (26,000)	2	\$ 8,530	\$3.15	\$10.50	\$13.65
100 (26,000)	1	\$10,020	\$3.68	\$ 9.90	\$13.67
200 (52,000)	2	\$ 5,460	\$2.01	\$ 8.70	\$10.71

1. Based on actual costs of Johnson City composting plant with modifications with 7½ percent bank financing over 20 years. Straight line depreciation of buildings and equipment over 20 years.

2. Includes land costs estimated at \$800/acre (Johnson City, Tenn.).

3. Does not include costs for landfilling rejects. For an estimate of these costs, add \$0.88, \$0.72, and \$0.52 to the 50-, 100-, and 200-tons-per-day plants respectively. Costs for landfilling refuse generated in a municipality the size of Johnson City range from \$2.00 to \$5.00 per ton of refuse deposited.^{9,10} Using the average of \$3.50, the 12.5 tons of compost plant rejects deposited each day would cost \$43.75 or \$0.88 per ton of refuse processed. Corresponding landfill costs for cities operating 100- and 200-ton-per-day composting plants are about \$2.75 and \$2.00 respectively per ton of refuse deposited.^{9,10} Costs for landfilling the rejects from these plants would be \$0.72 and \$0.52 per ton respectively.

4. Actual costs of the research and development PHS-TVA Composting Plant at Johnson City, Tennessee.

The cost estimates include equipment for processing sewage sludge. Also included are costs for land, depreciation, and debt service. Because use of compost is normally seasonal, the estimates include land area for storage of 6 month's production of compost in rectangular piles 15 ft high. Land costs were assumed at \$800 per acre--consistent with land values near Johnson City. If land costs were assumed at \$1,500 per acre, the capital cost for the 100- and 200-ton plants on two shifts would increase by no more than one cent per ton of refuse processed. For the 100-ton plant on one shift, the increase would be about 3 cents per ton of refuse processed.

Details of the construction and operating costs projections to these plants are provided in Tables 28, 29, 30, 31, 32, and 33.

Plant Income. None of the compost produced has been sold. Also, salvaging of potentially salable materials has not been practiced. Therefore, the project has not obtained cost data with respect to potential plant income from such sources. The potential income of composting plants, other economic considerations and the potential of windrow composting in solid waste resource management systems, will be discussed in a report entitled "Composting of Municipal Solid Waste in the United States."¹¹

Demonstration and Utilization

None of the compost produced at the Johnson City plant has been sold. Prior to March 1969, the Bureau of Solid Waste Management had asked TVA to restrict the uses to which it was put pending the outcome

TABLE 28

USPHS-TVA PLANT CONSTRUCTION COSTS
PROJECTED TO A 50-TON PER DAY PLANT *

Site improvements		\$ 88,100
Buildings		
Receiving building		75,000
Processing building		90,000
Open shed (6,000 square feet)		25,000
Office and laboratory		20,000
Receiving machinery and equipment		
Hopper conveyor and leveling gate		43,300
Scale (automatic tally)		18,500
Processing		
Elevating conveyor (sorting belt), with magnetic separator		28,500
Reject hopper		8,100
Raspig machine (grinder)		68,000
Chuting		9,000
Conveyors		10,400
Sludge dewatering apparatus, degritter, thickening tank and sludge pump		68,000
Ground refuse-sludge mixer		11,000
Sludge piping		19,100
Power and control system		42,000
Loading bin with bucket elevator		16,000
Ballistic separator		20,000
Composting field, surface preparation (crushed stone) and water lines		38,700
Regrinding and screening		50,000
Gasoline dispensing installation		2,800
Mobile equipment, including front end loaders and turner		56,000
Tools, small equipment, etc.		7,000
Office and laboratory equipment		5,000
	Construction Total	\$819,500
Land costs (10.5 acres at \$800/acre)		8,400
	Total	\$827,900

* Based on costs of Johnson City plant (1966-67), revised for lower building costs and some changes in machinery and equipment. Plant would operate one shift of 8 hours each day. To operate this plant on two shifts for 100 tons of raw refuse per day the receiving building apron would require enlargement and cover and the site would require expansion to 15.5 acres. The added cost would be \$21,000 for receiving area and \$4,000 for land, bringing total to \$852,900.

TABLE 29

USPHS-TVA PLANT CONSTRUCTION COSTS
PROJECTED TO A 100-TON PER DAY PLANT *

Site improvements	\$ 90,000
Buildings	
Receiving building	96,000
Processing building	90,000
Open shed (6,000 square feet)	25,000
Office and laboratory	20,000
Receiving machinery and equipment	
Hopper conveyor and leveling gate	43,300
Scale (automatic talley)	18,500
Processing	
Elevating conveyor (sorting belt), with magnetic separator	28,500
Reject hopper	10,000
Rasping machine (grinder)	136,000
Chuting	12,000
Conveyors	12,500
Sludge dewatering apparatus, degritter, thickening tank and sludge pump	92,000
Ground refuse-sludge mixer	16,500
Sludge piping	20,000
Power and control system	45,000
Loading bin	20,000
Ballistic separator	20,000
Composting field, surface preparation (with crushed stone) and water lines	62,000
Regrinding and screening	50,000
Gasoline dispensing installation	2,800
Mobile equipment, including front end loaders and turner	67,000
Tools, small equipment, etc.	7,000
Office and laboratory equipment	<u>5,000</u>
Construction Total	\$ 989,100
Land costs (15.5 acres at \$800/acre)	<u>12,400</u>
Total	\$1,001,500

* Based on unit costs (1966-67) at Johnson City, revised for less expensive buildings and some changes in machinery and equipment. Plant would operate one shift of 8 hours each day. To operate this plant on two shifts for a capacity of 200 tons of raw refuse per day would require enlargement of the receiving building, enlargement of the sludge thickening tank, expansion of the site to 26.5 acres, and the addition of one front end loader and one windrow turner. Added costs would be \$20,000 for receiving, \$15,000 for sludge handling, \$8,800 for land, and \$47,100 for mobile equipment, bringing the total to \$1,092,400.

TABLE 30
USPHS-TVA PLANT ANNUAL OPERATING
COSTS PROJECTED TO A 50-TON
PER DAY PLANT (one shift) ^{1/}

	-OPERATIONS-					-MAINTENANCE-				
	Salaries & Benefits	Electric Power	Truck Use	Supplies & Materials	Miscellaneous	Total	Salaries & Benefits	Supplies & Materials	Repairs	Total
Receiving ^{2/}	\$ 11,400	\$ 130	\$	\$ 50	\$	\$ 11,580	\$ 1,650	\$ 500	\$ 500	\$ 2,650
Picking & Sorting	17,200	40		300		17,540	1,000	100	100	1,200
Disposal of Rejects ^{3/}	9,650		2,700	70		12,420	850	100		950
Grinding (rasper)	4,550	1,330		100		5,980	4,750	5,000	200	9,950
Composting	18,950	20	1,740	1,000	100	21,810	8,200	2,000	1,000	11,200
Curing	1,750		1,220	50		3,020			100	100
Storage	5,200		1,220	50		6,470			100	100
Operation & Maintenance of Grounds, Buildings, & Utilities		1,580			200	1,780	6,450	800	500	7,750
Cleanup of Process & Receiving Buildings	11,600			150	300	12,050				
Office & Laboratory ^{4/}	7,250			800	500	8,550				
Regrinding & Screening	8,200	1,360	1,220	500		11,280	3,000	500	500	4,000
Sewage Sludge Processing	5,300	1,070		500		6,870	1,900	500	1,000	3,400
	101,050	5,530	8,100	3,570	1,100	119,350	27,800	9,500	4,000	41,300
Other (including Administrative & Overhead)	8,600			5,000	1,000	14,600	2,400			2,400
	\$109,650	\$5,530	\$8,100	\$8,570	\$2,100	\$133,950	\$30,200	\$9,500	\$4,000	\$43,700
										\$177,650

1. Plant capacity of 50 tons of raw refuse per day in one 8-hour shift. Costs are for 260 days of operation for a total of 13,000 tons per year.

2. At plant site.

3. Includes haulage to a landfill site but no landfilling costs.

4. For laboratory and office functions only. Does not include cost of building maintenance.

TABLE 31

USPHS-TVA PLANT ANNUAL OPERATING
COSTS PROJECTED TO A 100-TON
PER DAY PLANT (two shifts) ^{1/}

	- - - - - OPERATIONS - - - - -				- - - - - MAINTENANCE - - - - -			
	Salaries & Benefits	Electric Power	Truck Use	Supplies & Materials	Miscellaneous	Salaries & Benefits	Supplies & Materials	Repairs
	Total					Total		Total
Receiving ^{2/}	\$ 18,700	\$ 195	\$	\$ 100	\$	\$ 18,995	\$ 1,000	\$ 1,000
Picking & Sorting	38,450	55		600		39,105	200	500
Disposal of Rejects ^{3/}	18,050		4,590	150		22,790	200	
Grinding (rasper)	7,800	1,935		200		9,935	9,550	400
Composting	31,900	30	2,345	2,000	200	36,475	4,000	2,000
Curing	3,350		1,645	100		5,095		200
Storage	10,050		1,645	100		11,795		200
Operation & Maintenance of Grounds, Buildings, & Utilities		1,435			200	1,635	1,000	500
Cleanup of Process & Receiving Buildings	12,100			200	400	12,700		
Office & Laboratory ^{4/}	7,250			1,000	600	8,850		
Regrinding & Screening	15,600	1,635	1,645	1,000		19,880	1,000	1,000
Sewage Sludge Processing	9,550	1,390		1,000		11,940	1,000	2,000
Other (including Administrative & Overhead	172,800	6,675	11,870	6,450	1,400	199,195	17,950	7,800
	13,600				1,000	14,600		
	\$186,400	\$6,675	\$11,870	\$6,450	\$2,400	\$213,795	\$17,950	\$7,800
							2,400	2,400
							\$33,400	\$59,150
								\$272,945

1. Plant of 50 tons of raw refuse capacity in one 8-hour shift working two 8-hour shifts.

Costs are for 260 days of operation for a total of 26,000 tons per year.

2. At plant site.

3. Includes haulage to a landfill site but no landfilling costs.

4. For laboratory and office functions only. Does not include cost of building maintenance.

TABLE 32

USPHS-TVA PLANT ANNUAL OPERATING
COSTS PROJECTED TO A 100-TON
PER DAY PLANT (one shift) ^{1/}

	- - - - - OPERATIONS - - - - -					- - - - - MAINTENANCE - - - - -				
	Salaries & Benefits	Electric Power	Truck Use	Supplies & Materials	Miscel- laneous	Total	Salaries & Benefits	Materials & Supplies	Repairs	Total
Receiving ^{2/}	\$ 16,150	\$ 130	\$	\$ 100	\$	\$ 16,380	\$ 1,750	\$ 1,500	\$ 1,000	\$ 4,250
Picking & Sorting	29,250	75		600		29,925	1,000	200	500	1,700
Disposal of Rejects ^{3/}	18,050		5,385	150		23,585	850	200		1,050
Grinding (rasper)	7,300	2,715		200		10,215	5,350	9,550	400	15,300
Composting	29,550	25	2,600	2,000	200	34,375	9,500	4,000	2,000	15,500
Curing	3,350		1,825	100		5,275			200	200
Storage	9,750		1,825	100		11,675			200	200
Operation & Maintenance of Grounds, Buildings, & Utilities		1,485			200	1,685	6,450	1,000	500	7,950
Cleanup of Process & Receiving Buildings	11,600			200	400	12,200				
Office & Laboratory ^{4/}	7,250			1,000	600	8,850				
Regrinding & Screening	15,600	1,710	1,825	1,000		20,135	4,000	1,000	1,000	6,000
Sewage Sludge Processing	6,550	1,400		1,000		8,950	2,300	1,500	1,500	5,300
Other (including Administrative & Overhead	154,400	7,540	13,460	6,450	1,400	183,250	31,200	18,950	7,300	57,450
	13,600				1,000	14,600	2,400			2,400
	\$168,000	\$7,540	\$13,460	\$6,450	\$2,400	\$197,850	\$33,600	\$18,950	\$7,300	\$59,850
										\$257,700

1. Plant capacity of 100 tons of raw refuse per day in one 8-hour shift. Costs are for 260 days of operation for a total of 26,000 tons per year.
2. At plant site.
3. Includes haulage to a landfill site but no landfilling costs.
4. For laboratory and office functions only. Does not include cost of building maintenance.

TABLE 33

**USPHS-TVA PLANT ANNUAL OPERATING
COSTS PROJECTED TO A 200-TON
PER DAY PLANT (two shifts) ^{1/}**

	- - - - - OPERATIONS - - - - -					- - - - - MAINTENANCE - - - - -				
	Salaries & Benefits	Electric Power	Truck Use	Supplies & Materials	Miscel- laneous	Total	Salaries & Benefits	Materials	Repairs	Total
Receiving ^{2/}	\$ 29,550	\$ 190	\$	\$ 200	\$	\$ 29,940	\$ 2,450	\$ 3,000	\$ 2,000	\$ 7,450
Picking & Sorting	62,700	105		1,200		64,005	1,400	400	1,000	2,800
Disposal of Rejects ^{3/}	35,700		9,185	300		45,185	1,150	300		1,450
Grinding (rasper)	13,100	3,730		400		17,230	6,000	19,100	800	25,900
Composting	52,200	30	4,950	4,000	400	61,580	13,750	8,000	4,000	25,750
Curing	6,500		3,470	200		10,170			400	400
Storage	19,600		3,470	200		23,270			400	400
Operation & Maintenance of Grounds, Buildings, & Utilities		1,400			400	1,800	6,650	1,200	500	8,350
Cleanup of Process & Receiving Buildings	12,000			300	500	12,800				
Office & Laboratory ^{4/}	14,700			1,200	1,000	16,900				
Regrinding & Screening	29,000	2,220	3,470	2,000		36,690	6,000	2,000	2,000	10,000
Sewage Sludge Processing	9,950	1,795		2,000		13,745	3,600	3,000	3,000	9,600
	285,000	9,470	24,545	12,000	2,300	333,315	41,000	37,000	14,100	92,100
Other (including Administrative & Overhead	22,700				1,000	23,700	3,300			3,300
	\$307,700	\$9,470	\$24,545	\$12,000	\$3,300	\$357,015	\$44,300	\$37,000	\$14,100	\$95,400
										27,000
										\$452,415

1. Plant capacity of 100 tons of raw refuse in one 8-hour shift working for two 8-hour shifts.

Costs are for 260 days of operation for a total of 52,000 tons per year.

2. At plant site.

3. Includes haulage to a landfill site but no landfilling costs.

4. For laboratory and office functions only. Does not include cost of building maintenance.

of pathogen survival studies. These restrictions and the lack of a finished product has limited the activity of the Division of Agricultural Development, TVA, in its utilization studies.

The TVA agriculturist assigned to the project has, however, been active in setting up demonstrations where the unfinished material could be used and where owners of the sites agreed to abide by the restrictions. The demonstration areas are on public lands or the land of private owners who have agreed to allow the agriculturist to supervise the application and to follow the progress of the plantings.

Due to the troubles experienced with the final grinding and screening equipment which was not completed until February 1969, the bulk of the material used in Fiscal Year 1969 was unfinished (unreground or screened). It represents 80 percent of the compost produced in the year.

The demonstration sites include tobacco, corn, gardens, grass or sod establishment, erosion control and reclamation, orchards, shrubs and flowers, golf courses, soybeans, and miscellaneous. TVA experimental test plots are in corn and grain sorghum, each involving 52 test plots, 12 x 30 ft each, in which various application rates are being examined, some with fertilizers and some without. Another concerns an evaluation of compost on Bermuda grass. Appendix III provides preliminary results of the experiments.¹²

The rates of application on the demonstration plantings range from 10 to 100 tons per acre for corn and 5 to 30 tons per acre for tobacco. The agriculturist hopes to evaluate the merits of application rates of 4 to 200 tons per acre and various rates of fertilization in several seasons over the next 3-1/2 years.

Three other demonstrations deserve special mention. Two of these involve erosion control and reclamation of strip mine spoil bank areas, one project in cooperation with the TVA Strip Mine Reclamation Section, and one project in cooperation with the Southern Soil Conservation Committee in Mercer County, West Virginia. Approximately 100 tons were shipped to the Oak Ridge National Laboratory for use as a soil amendment in a radioactive burial ground area being used for special ecological studies.

In addition to demonstration and research with compost in the vicinity of Johnson City, the Division of Agricultural Development undertook research into the effect of compost on a planting of pine tree seedlings at Holder, Citrus County, Florida. Because of the distance and cost for shipment from Johnson City, arrangements were made to obtain compost from the Gainesville Municipal Waste Conversion Authority plant at Gainesville, Florida. Through cooperation from the Soils Department, University of Florida, compost was obtained at no cost and advice and consultation were obtained from the staff. The physical appearance of this compost compared well with the Johnson City compost, but the moisture content was about twice and the nitrogen content 50 to 80 percent that of the compost as used in demonstrations at Johnson City.

REFERENCES

1. Mason, H. G. Extending life of disposal areas. Compost Science, 10(1-2):26-31, Spring-Summer 1969.
2. Reclamation of municipal refuse by composting. Technical Bulletin No. 9. Berkeley, Sanitary Engineering Research Laboratory, University of California, June 1953. 89 p.
3. Wiley, J. S., and O. W. Kochtitzky. Composting developments in the United States. Compost Science, 6(2):5-9, Summer 1965.
4. Gotaas, H. B. Composting-sanitary disposal and reclamation of organic wastes. World Health Organization Monograph Series No. 31. Geneva, World Health Organization, 1956. 44 p.
5. Morgan, M. T., and F. W. Macdonald. Tests show MB tuberculosis doesn't survive composting. Journal of Environmental Health, 32(1):101-108, July-Aug. 1969.
6. Belding, D. L. Basic clinical parasitology. New York, Appelton-Century-Crofts, Inc., 1958. 469 p.
7. Scott, J. S. Health aspects of composting with night soil. World Health Organization Expert Committee on Environmental Sanitation, 3rd session, Geneva, July 27-31, 1953. 8 p.
8. Wilson, D. L. Laboratory procedure for the gravimetric determination of carbon and hydrogen in solid wastes (for methods manual); a Division of Research and Development open-file report (RS-03-68-17). [Cincinnati], U.S. Department of Health, Education, and Welfare, 1970. 35 p. [Restricted distribution.]
9. Muhich, A. J. Sample representatives and community data. In Black, R. J., et al. The national solid wastes survey; an interim report. [Cincinnati], U.S. Department of Health, Education, and Welfare, [1968]. p. 7-25.
10. Sorg, T. J., and H. L. Hickman, Jr. Sanitary landfill facts. 2d ed. Public Health Service Publication No. 1792. Washington, U.S. Government Printing Office, 1970. 30 p.
11. Breidenbach, A. W., et al. Composting of municipal solid wastes in the United States. Washington, U.S. Government Printing Office, 1971. 103 p.
12. Mays, D. A., E. M. Evans, R. C. Dyrum, and C. E. Worley. Excerpt Forage Research Report No. 6. Summary of 1969 forage investigations. Soils and Fertilizer Research Branch, Tennessee Valley Authority, Muscle Shoals, Alabama.

APPENDIX I

Methods Used for Chemical Analyses

Test for Moisture. Moisture contents were determined by oven drying at 100 C using 2,000 gram or larger samples. In most cases a drying period of 24 hr was used as the water content was rarely over 60 percent by wet weight. Moisture content was calculated by the relation:

$$\frac{100 \text{ (loss in weight)}}{\text{(net wet weight)}} = \% \text{ moisture (wet basis)}$$

Digestion of Compost Samples for Elemental Analyses. Digest from 2.0 to 3.0 grams of compost (dried, finely ground, and weighed to the nearest milligram) in a mixture of 20 milliliters of concentrated sulfuric acid and 50 milliliters of concentrated nitric acid in a Kjeldahl flask for 2 hr or until clear, adding additional nitric acid if necessary. Filter and dilute this to 500 milliliters in a volumetric flask and save for further analyses.

Test for Nitrogen (Organic and Ammoniacal). The test used in the project laboratory is a modification of the Kjeldahl-Wilfarth-Gunning method described in Appendix A, *Municipal Refuse Disposal*, American Public Works Association, 2 ed., 1966.

Equipment - Kjeldahl flasks for digestion and distillation,
800 milliliter; exhaust hood and special stack
to outside for venting acid fumes during digestion;

Kjeldahl connecting bulbs (use bulbs 5 to 6 centimeters in diameter, fit lower end with rubber stopper, and connect upper end to a condenser with rubber tubing); Erlenmeyer flasks, 500 milliliter.

Reagents - Standard sulfuric acid, 0.1N; standardize by any official method.

Boric acid solution, 40 g/l.

Sulfuric acid, 93 to 96 percent H_2SO_4 , free from nitrates and $(\text{NH}_4)_2\text{SO}_4$.

Mercuric oxide, reagent grade, free from nitrogen.

Sodium hydroxide-thiosulfate solution:

dissolve 450 grams of NaOH, free from nitrates, in water and allow to cool; add 80 grams of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, keeping solution cool, and make to 1 liter with water.

Methyl red indicator: dissolve 1 gram of methyl red in 200 milliliters of 95 percent ethyl alcohol.

Potassium sulfate, K_2SO_4 .

Granulated zinc.

Procedure - Weigh to fourth decimal place 0.7 to 2.5 grams of redried sample (indirectly from aluminum sample container) into a piece of Whatman No. 1 filter paper (9 centimeters). Fold paper and

introduce into digestion flask. Add 15 to 18 grams of K_2SO_4 , about 0.7 grams of mercuric oxide, and 25 milliliters of concentrated H_2SO_4 . Heat gently until frothing ceases, then boil briskly, continuing digestion for about 2 hr after the mixture is colorless or nearly so. Cool, add 200 milliliters of water, and dissolve cake. Add 1 gram of granulated zinc to prevent bumping and 75 milliliters of alkali-thiosulfate solution, pouring down the side of the flask so that it does not mix at once with the acid solution. Connect flask immediately to the condenser by means of the Kjeldahl connecting bulk, taking care that the tip of the condenser extends below the surface of the standard acid in the 500-milliliter flask, which acts as a receiver. Mix the contents by shaking and distill into 50 milliliters of the boric acid solution until about 200 milliliters of distillate has been obtained. The first 150 milliliters of the distillate usually contains all of the NH_3 . It is helpful to mark the receiving flasks at about 200 milliliters and distill to the mark. Titrate with the standard acid solution, using the methyl red indicator.

$$\text{Calculations - } \frac{\text{ml } 0.10\text{N } \text{H}_2\text{SO}_4 \times 0.14}{\text{Weight of sample (grams)}} = \% \text{ Nitrogen}$$

Determination of Carbon Content of Compost and Refuse. Determinations for carbon content was made by the Research Services Laboratory, Division of Research and Development, BSWM, in Cincinnati, where special procedures were developed. The gravimetric method for determination of carbon and hydrogen is described in an open file report.⁸

Test for Phosphorus. Dilute the previously digested sample to 500 milliliters in a volumetric flask and determine the phosphorous content as in *Standard Methods for the Examination of Water and Wastewater*, 12th ed., 1965, p. 234-236, with the following modifications:

1. Use only recently digested samples, no more than 1 week old. Old samples give erratic, inaccurate results.
2. Dilute 5 ml of digested material to 100 ml for the determinations.
3. Standard addition must be used with this method. Make two additional preparations of each sample and add 0.05 milligrams and 0.10 milligrams phosphorus to each, respectively. It was found that there is a color suppressant in the compost that will result in low values if the analyses are performed against a standard curve. This interference is readily overcome with the standard addition technique, giving accurate, reliable results.

Tests for Sodium, Potassium, Calcium, and Magnesium. Using previously digested samples of compost, these elements are determined by flame photometry using the methods as described in Dean, John A., *Flame Photometry*, McGraw-Hill, 1960, New York, p. 153-179.

Test for Boron. Using a digested compost sample, boron is determined by two methods as given in Snell and Snell, *Colorimetric Methods of Analysis*, Vol. 11A, D. Van Nostrand Company, 1959, Princeton, New Jersey. Page 594 of this text describes a method using quinalizarin, and page 596 describes a method using carminic acid (carmine red). Both of these methods were found to be satisfactory; however, both methods should be employed with each sample tested to assure accurate results.

Test for Copper. Add 4 milliliters of a digested sample (2 to 3 grams in 500 milliliters of water) to a separatory funnel, then add 5 milliliters of 10 percent hydroxylamine hydrochloride and 10 milliliters of 30 percent sodium citrate. Add concentrated NH_4OH by drops until the pH is between 4 and 6. Then add 10 milliliters of 10 percent neocuproine, mix and extract with 10 milliliters of CHCl_3 . Let the layers separate, draw off the chloroform layer and read the absorbance in a spectrophotometer at 457 millicrons. Run standards with a range of from 10 to 50 ppm copper. The reference for this test is Snell and Snell, *Colorimetric Methods of Analysis*, page 75.

Test for Iron. Dilute the previously digested sample to 500 milliliters in a volumetric flask. Pipet 5.0 milliliters into a separatory funnel, add 10 milliliters 5 percent KCNS solution and extract the red complex with exactly 50.0 milliliters ether. Draw

off the aqueous phase and read the absorbance of the ether phase in a spectrophotometer at 440 millimicrons. For standards use 20, 50, and 100 ppm iron (Fe^{+3}). Compute the concentration of the sample directly from the standard curve in ppm. The iron content of the sample is determined by the relation:

$$\frac{\text{Concentration of sample (ppm)}}{20 \times \text{initial sample wt.}} = \% \text{ Iron}$$

Fairly reliable results can be obtained by simply boiling the sample in strong hydrochloric, nitric, or sulfuric acid (3N to 6N) to dissolve the iron, filtering and washing the resultant mass, and diluting the filtrate to 500 ml, then proceeding as above. This would eliminate the digestion step, thus giving a more rapid analysis with results accurate enough for routine analysis. The reference for the iron test is Snell and Snell, *Colorimetric Methods of Analysis*, Vol. IIA, p. 229-231.

Test for Aluminum. Remove iron from the sample as described in page 246 of Snell and Snell, *Colorimetric Methods of Analysis*, Vol. II, Van Nostrand, New York, 1949.

After removal of the iron is complete, determine the aluminum by following the directions given on pages 48-50 of the above reference.

Tests for Manganese, Nickel, Zinc, Mercury, and Lead. These elements are present in compost in trace amounts, and their upper limits of concentration were set using methods as described in Feigl, Fritz, *Qualitative Analysis by Spot Tests*, Elsevier Publishing Company, New York,

1946. These elements can be quantitatively determined by atomic absorption spectroscopy or by mass spectroscopy. Polarographic techniques may also be used, but difficulty will be encountered since the compost contains an abundance of elements with electrode half-potentials similar to these, and special solvent extraction or masking techniques would have to be used to achieve reliable results. Atomic absorption spectroscopy is probably the easiest, most rapid and accurate technique to employ for these elements.

Determination of Chemical Oxygen Demand (C.O.D.) The reference used for this determination is *Standard Methods for the Examination of Water and Waste-water*, 12th ed., 1965, p. 510-514, where the technique and standardization procedure can be found.

Reagents - Potassium dichromate solution, 1.00N.

Standardized ferrous ammonium sulfate.

Concentrated sulfuric acid.

Ferroin indicator.

Procedure - Weigh out 0.2 to 0.3 grams of finely ground, dry, compost (2 millimeter mesh) to the nearest milligram and place the sample in a 250 milliliter Erlenmeyer flask. Pipette in exactly 50.0 milliliters of 1.00N $K_2Cr_2O_7$, add 30 milliliters of water and 20 milliliters of concentrated H_2SO_4 . Place on a hotplate and boil gently for 1 hr, adding water to compensate for evaporation. Dilute to 250

milliliters in a volumetric flask, mix well, pipette 10.0 milliliters into a 500 milliliter flask and add about 100 milliliters of water. Titrate with standardization ferrous ammonium sulfate (about 0.1 to 0.2N) using ferroin as an indicator.

$$\text{Calculations - C.O.D.} = \frac{(A - B) \times C \times 200}{\text{grams of sample}} \text{ (in milligrams/gram)}$$

where:

A = milliliters of titrant used for blank

B = milliliters of titrant used for sample

C = normality of titrant

It is advisable to run a duplicate of the original sample and a duplicate of each dilution. Good precision was found in duplicate assays, indicating that the method is stable and reproducible for a given sample of compost. This observation is further substantiated by the results plotted in Figure 56, which show the COD in milligrams/gram of randomly selected windrows versus age. Johnson City compost, at 8 weeks, showed a COD of less than 700 mg/gram, as opposed to around 900 mg/gram for fresh refuse.

Determination of Cellulose Content. Two methods for the determination of cellulose content were used in the laboratory, the anthron colorimetric method and the gravimetric method.

(Anthrone Method)

Reagents - Diluted H_2SO_4 (760 ml conc. H_2SO_4 + 300 ml water)

Anthrone reagent: 1 gram anthrone in 500 ml cold
96% H_2SO_4 . Let stand at room
temperature 4 hr before use.

Benzene

Pure cellulose standard

Procedure - Weigh out a finely ground and redried compost sample to the nearest milligram, place in a Soxhlet extractor, and extract with benzene for 8 hr. Dry the composite sample and weight it in order to compute the percent material extracted with benzene. Extract this sample again with hot water for 8 hr. Dry the sample and weigh it in order to compute the percent material extracted with water. Take between 0.5 to 1.0 gram of the composite sample weighed to the nearest milligram and place it in a 250 milliliter beaker, wet it with a few drops of ethanol, methanol, or acetone. Pipet in 10.0 milliliters water, then 60.0 milliliters diluted sulfuric acid and stir to dissolve the cellulose solution into a 500 milliliter volumetric flask and dilute to 500 milliliters. Pipet 1 milliliter of this into a test tube, add 10.0 milliliters anthrone reagent, mix, seal the tube and heat in a 100 C bath for 15 min. Cool to room temperature and

read the absorbance with a spectrophotometer at 630 millimicrons. Run cellulose standards to bracket the sample concentration and a blank with each series of samples. A blank and standards must be included with each group of samples heated in the 100 C bath.

$$\text{Calculations - \% cellulose} = \frac{W_c \times (100 - [\% E_b + \% E_w])}{\text{grams of extracted sample}}$$

where:

W_c = weight of cellulose found in grams

E_b = benzene extract

E_w = water extract

Note: If all the sample can be recovered and used after the benzene and water extractions, then it is unnecessary to compute the percent of extracted material. Simply know the initial weight of the sample, the number of grams found (from the anthrone standard curve) and compute the percent cellulose from this. This is easily accomplished by placing 0.5 gram to 1.0 gram of compost in a porcelain thimble with an asbestos filter, capping with glass wool, extracting, and then washing all the sample into a beaker and proceeding with the determination as above.

(Gravimetric Method)

Reagents - Concentrated nitric acid

Glacial acetic acid

Benzene

Ether

Methanol

Acetone

Procedure - Weigh out about 1 gram of redried, finely ground compost to the nearest milligram, place in a 125 milliliter Erlenmeyer flask and add 6 milliliters water, 24 milliliters glacial acetic acid, and 2 milliliters concentrated nitric acid. Bring to a gentle boil on a hotplate for 20 min, cool to about 80 C, add 50 milliliters benzene and swirl vigorously to extract materials soluble in benzene. Set up a Gooch crucible with an asbestos filter on a suction flask, decant as much of the benzene layer as possible into the filter (with suction) taking care not to let the bottom layer spill over. Then add 50 milliliters of ether to the flask, swirl vigorously, let settle and decant all the liquid into the crucible. Wash all the solid material into the crucible with acetone, taking care not to leave any behind. Wash the filter cake thoroughly with successive portions of hot benzene, hot methanol, and ether. After washing, clean the outside of the crucible, place in an oven to dry, cool in a desiccator, weigh to

the nearest milligram and ignite at 625 C for 1 hr. Cool, weigh, and report the loss on ignition.

Calculations -
$$\frac{\text{Loss on ignition} \times 100}{\text{Initial sample weight}} = \% \text{ Cellulose}$$

Discussion - Duplicate samples should always be run to assure precision. Swirling the benzene with the hot reaction mixture is necessary to assure rapid filtering of the successive solvents used. Compost contains a tar-like material that plugs the filter, and most of this is soluble in benzene.

An alternate approach is provided by combining the two methods. Complete the solvent washings as in the gravimetric method, then dissolve the entire sample as in the anthrone method and determine the cellulose colorimetrically. This was done three times with a 0-day composite compost sample, and the results were 49.4 percent, 49.4 percent, and 49.6 percent. The gravimetric method on the same sample yielded 50.2 percent, 50.0 percent, and 50.3 percent. The higher results indicate that some substances were not removed by the extractions (0.7%) and were not cellulose, but were lost on ignition.

Analyses were performed on samples to which known amounts of cellulose had been added to further check the gravimetric method.

		% Cellulose				
0-day compost	found	50.3	55.1	60.6	65.4	
	theoretical		55.2	60.5	65.4	
56-day compost	found	24.3	37.6	29.4	60.9	
	theoretical		36.8	28.7	61.5	
1-year compost	found	19.1	28.0	38.3	48.1	60.8
	theoretical		28.2	39.1	49.2	61.1

The gravimetric method is recommended because it is more rapid and easier to perform than the colorimetric anthrone method.

Tests for Volatile Solids and Ash. This test was made in accordance with the procedure described in Appendix A, *Municipal Refuse Disposal*, American Public Works Association, 2d ed., 1966, p. 381.

Test for Lipids. Lipids content was determined by the ether extract method described in Appendix A, *Municipal Refuse Disposal*, American Public Works Association, 2d ed., 1966, p. 381.

Tests for Sugars and Starch. Extract a carefully weighed sample (about 3-5 grams) with ether in a Soxhlet extractor for 6 hr. Remove the ether, dry the sample, and extract with 95 percent ethanol for 8 hr. - Dry the sample and extract again with water for 15 hr. Determine the sugars in the ethanol extract and the starch in the water extract by the anthrone method as described in the Determination of Cellulose, page 77, or in Appendix A,, *Municipal Refuse Disposal*, American Public Works Association, 2d ed., 1966, p. 386.

Glucose alone may be determined by using a device known as a "glucostat" manufactured by the Worthington Biochemical Company, available from Matheson Scientific Company.

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
 F. Y. Expired 25%

EASTERN DISTRICT			MONTH OF SEPTEMBER 19 69		Budget	Per Cent Expended
Account Title			Account Number	Expense This Month Fiscal Year To Date		
<u>USPHS-TVA Composting Plant</u>						
<u>Delivery and Receiving</u>						
<u>Operation</u>	HRS	YTD	012-01.11			
11 - Salaries, ST	161.5	502.0		618	1,886	
OT	9.0	13.0		38	58	
12 - Benefits				107	312	
Total salary expense				763	2,256	
26 - Supplies and materials				-	-	
Total				763	2,256	
<u>Maintenance</u>			012-01.12			
11 - Salaries, ST	124.0	200.0		573	917	
OT	25.5	26.5		152	158	
12 - Benefits				115	171	
Total salary expense				840	1,246	
25 - Tire repairs, loader repairs				-	15	
26 - Supplies and materials				163	264	
Total				1,003	1,525	
Total Delivery and Receiving				1,766	3,780	
<u>Picking and Sorting</u>						
<u>Operation</u>			012-02.11			
11 - Salaries, ST	184.5	575.5		650	2,029	
OT	3.0	5.0		13	22	
12 - Benefits				113	352	
Total salary expense				776	2,403	
26 - Supplies and materials				13	38	
Total				789	2,441	
<u>Maintenance</u>			012-02.12			
11 - Salaries, ST	-	1.0			4	
OT	-	-			-	
12 - Benefits					1	
Total salary expense				-	5	
26 - Supplies and materials					-	
Total				-	5	
Total Picking and Sorting				789	2,446	
<u>Grinding</u>						
<u>Rasper Operation</u>			012-03.11			
11 - Salaries, ST	125.0	340.5		506	1,393	
OT	.5	7.5		3	36	
12 - Benefits				88	241	
Total salary expense				597	1,670	
26 - Supplies and materials				-	-	
Total				597	1,670	

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
F. Y. Expired 25%

EASTERN			DISTRICT		MONTH OF SEPTEMBER		19 69	
Account Title			Account Number	Expense		Budget	Per Cent Expended	
				This Month	Fiscal Year To Date			
<u>Grinding - Continued</u>			012-03.12					
<u>Rasper Maintenance</u>								
11 - Salaries, ST	1.0	114.0		5	547			
OT	-	32.0		-	191			
12 - Benefits				1	79			
Total salary expense				6	817			
26 - Supplies and materials			8	792				
Total			14	1,609				
<u>Hammermill Operation</u>			012-03.21					
11 - Salaries, ST				-	141			
OT	-	-		-	25			
12 - Benefits				-	166			
Total salary expense				-	166			
26 - Supplies and materials								
Total								
<u>Hammermill Maintenance</u>			012-03.22					
11 - Salaries, ST				84	156			
OT	-	1.0		-	5			
12 - Benefits				4	17			
Total salary expense				88	178			
26 - Hammers, belts, miscellaneous				26	26			
Total			114	204				
Total Grinding			725	3,649				
<u>Sludge Thickening and Mixing Operation</u>			012-04.11					
11 - Salaries, ST				25	364			
OT	-	2.0		-	9			
12 - Benefits				4	62			
Total salary expense				29	435			
26 - Supplies and materials				-	-			
60 - Mileage			-	8				
Total			29	443				
<u>Maintenance</u>			012-04.12					
11 - Salaries, ST				80	343			
OT	1.0	1.0		6	6			
12 - Benefits				14	59			
Total salary expense				100	408			
26 - Supplies and materials				-	120			
Total			100	528				
Total Sludge Thickening and Mixing			129	971				

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
F. Y. Expired 254

EASTERN			DISTRICT		MONTH OF SEPTEMBER		19 69	
Account Title			Account Number	Expense		Budget	Per Cent Expended	
				This Month	Fiscal Year To Date			
<u>Composting</u>								
<u>Hauling Operation</u>			012-05.11					
11 - Salaries, ST	141.0	453.0		564	1,806			
OT	2.0	4.0		10	19			
12 - Benefits				99	314			
Total salary expense				673	2,139			
26 - Supplies and materials				3	3			
60 - Truck use				365	948			
Total				1,041	3,090			
<u>Hauling Maintenance</u>			012-05.12					
11 - Salaries, ST	4.0	74.0		20	366			
OT	-	4.0		-	24			
12 - Benefits				3	47			
Total salary expense				23	437			
26 - Supplies and materials				33	67			
Total				56	504			
<u>Turning and Wetting Operation</u>			012-05.21					
11 - Salaries, ST	124.0	342.5		499	1,395			
OT	1.5	1.5		8	8			
12 - Benefits				85	240			
Total salary expense				592	1,643			
26 - Supplies and materials				12	79			
Total				604	1,722			
<u>Turning and Wetting Maintenance</u>			012-05.22					
11 - Salaries, ST	37.5	93.5		166	426			
OT	-	-		-	-			
12 - Benefits				29	70			
Total salary expense				195	496			
25 - Tire repairs				-	35			
26 - Supplies and materials				45	423			
Total				240	954			
Total Composting				1,940	6,270			
<u>Curing Operation</u>			012-06.11					
11 - Salaries, ST	1.0	25.0		4	101			
OT	-	-		-	-			
12 - Benefits				1	19			
Total salary expense				5	120			
26 - Supplies and materials				-	-			
60 - Truck use				-	8			
Total				5	128			

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
F. Y. Expired 25

EASTERN			DISTRICT		MONTH OF SEPTEMBER		1969
Account Title			Account Number	Expense		Budget	Per Cent Expended
				This Month	Fiscal Year To Date		
<u>Curing - Continued</u>	HRS	YTD					
<u>Maintenance</u>			012-06.12				
11 - Salaries, ST	-	-			-		
OT	-	-			-		
12 - Benefits					-		
Total salary expense				-	-		
26 - Supplies and materials				-	-		
Total				-	-		
Total Curing				5	128		
<u>Regrinding and Screening</u>							
<u>Operation</u>			012-07.11				
11 - Salaries, ST	152.0	450.5		661	1,925		
OT	-	-		-	-		
12 - Benefits				97	319		
Total salary expense				758	2,244		
26 - Supplies and materials				62	317		
60 - Truck use				325	640		
Total				1,145	3,201		
<u>Maintenance</u>			012-07.12				
11 - Salaries, ST	137.0	185.0		666	899		
OT	1.0	1.5		6	8		
12 - Benefits				89	125		
Total salary expense				761	1,032		
26 - Supplies and materials				34	81		
Total				795	1,113		
Total Regrinding and Screening				1,940	4,314		
<u>Hauling Rejects</u>							
<u>Operation</u>			012-08.11				
11 - Salaries, ST	151.5	481.5		603	1,918		
OT	4.5	9.5		22	46		
12 - Benefits				106	334		
Total salary expense				731	2,298		
26 - Supplies and materials				-	15		
60 - Truck use				341	907		
Total				1,072	3,220		
<u>Maintenance</u>			012-08.12				
11 - Salaries, ST	5.0	149.5		25	702		
OT	-	-		-	-		
12 - Benefits				4	82		
Total salary expense				29	784		
26 - Supplies and materials				11	155		
Total				40	939		
Total Hauling Rejects				1,112	4,159		

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
F. Y. Expired 25

EASTERN DISTRICT			MONTH OF SEPTEMBER		19 69	
Account Title	Account Number	Expense		Budget	Per Cent Expended	
		This Month	Fiscal Year To Date			
<u>Disposal of Nonmarketable Processed Mat'l</u>	012-09					
11 - Salaries, ST		270	633			
OT		13	21			
12 - Benefits		48	111			
Total salary expense		331	765			
60 - Truck use		32	101			
Total		363	866			
<u>Distributing Processed Material</u>	012-10					
11 - Salaries, ST		286	723			
OT		2	100			
12 - Benefits		48	122			
Total		336	945			
26 - Supplies and materials, services		16	24			
60 - Vehicle use		37	227			
Total		389	1,196			
<u>General Expense</u>						
<u>Operation of Grounds</u>	012-19.11					
11 - Salaries, ST		333	645			
OT		-	317			
12 - Benefits		21	75			
Total salary expense		354	1,037			
26 - Supplies and materials		2	2			
Total		356	1,039			
<u>Maintenance of Grounds</u>	012-19.12					
11 - Salaries, ST			25			
OT			3			
12 - Benefits			4			
Total salary expense		-	32			
26 - Supplies and materials		18	30			
60 - Truck use		-	-			
Total		18	62			
<u>Supervision</u>	012-19.21					
11 - Salaries, ST		1,046	3,187			
OT		125	536			
12 - Benefits		179	543			
Total salary expense		1,350	4,266			
21 - Travel expense		65	86			
60 - Vehicle use		101	255			
Total		1,516	4,607			

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
F. Y. Expired 25

EASTERN DISTRICT			MONTH OF SEPTEMBER		1969	
Account Title	Account Number		Expense		Budget	Per Cent Expended
			This Month	Fiscal Year To Date		
<u>Processing Building Cleanup</u>	012-19.31					
		HRS YTD				
11 - Salaries, ST		176.5 507.5	635	1,857		
OT		2.5 36.0	12	171		
12 - Benefits			104	317		
Total salary expense			751	2,345		
26 - Supplies and materials			-	-		
Total			751	2,345		
<u>Office and Lab Expense</u>	012-19.41					
11 - Salaries, ST		13.5 46.5	44	163		
OT		- 19.0	-	85		
12 - Benefits			5	25		
Total salary expense			49	273		
25 - Contractual services			-	14		
26 - Supplies and materials			-	26		
60 - Trailer rental			68	184		
62 - Office equipment use			12	36		
Total			129	533		
<u>Utilities</u>	012-19.51					
11 - Salaries, ST		8.0 33.0	36	155		
OT		-	-	-		
12 - Benefits			6	27		
Total salary expense			42	182		
23 - Power			355	720		
- Water			12	40		
- Telephone			-	59		
26 - Supplies and materials			19	94		
Total			428	1,095		
<u>Gasoline</u>	012-19.61					
26 - Gasoline purchases			437	449		
<u>Other</u>	012-19.71					
11 - Salaries, ST		264.0 445.0	1,084	1,788		
OT		3.0 14.0	17	69		
12 - Benefits			191	311		
Total salary expense			1,292	2,168		
21 - Travel			17	50		
22 - Freight			53	53		
26 - Supplies and materials			514	898		
60 - Vehicle use			15	80		
70 - Power Stores issues			-	99		
Total			1,891	3,348		
Total General Expense			5,528	13,479		

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

Per Cent of
 F. Y. Expired 25

EASTERN		DISTRICT		MONTH OF SEPTEMBER		19 69		
Account Title HRS YTD				Account Number	Expense		Budget	Per Cent Expended
					This Month	Fiscal Year To Date		
General Expense Distribution				012-20.61				
86 - Gas and oil issues to TVA					-153	-420		
Modification & Additions to Plant Equip.				012-50				
11 - Salaries, ST 90.0 324.5					448	1,604		
OT 3.0 19.0					18	116		
12 - Benefits					78	243		
Total salary expense					544	1,963		
22 - Freight					40	40		
23 - Equipment rental					180	180		
25 - Contractual services					-	-		
26 - Supplies and materials					118	345		
31 - Equipment					-	-		
60 - Truck use					-	-		
82 - Suborder costs					-	-		
Total					882	2,527		
Activity Totals - USPHS-TVA Compost Plant				012				
11 - Salaries, ST 2368.0 6678.5					9,929	28,095	104,770	27
OT 79.5 376.0					445	2,010	9,170	22
12 - Benefits					1,641	4,649	18,000	26
Total salary expense					12,015	34,754	131,940	26
21 - Travel					82	136	500	27
22 - Freight					93	93	1,000	09
23 - Telephone, util., equip. rental					548	999	6,000	17
25 - Other services					94	157	3,000	05
26 - Supplies and materials					1,426	4,139	15,000	28
31 - Equipment					-	-	20,000	-
60 - Transp. Branch equip. use					1,285	3,359	17,560	19
62 - Office equipment use					12	36	-	-
66 - Reproduction					13	13	-	-
70 - Warehouse issues					-	99	-	-
82 - Transferred costs					-	-	5,000	-
Gross					15,567	43,785	200,000	22
86 - Distribution				012-20	-153	-420	-5,000	08
Expenditures					15,414	43,365	195,000	22
50 - Income				012-999	-15,414	-43,365	-195,000	22
Net					-	-	-	-

APPENDIX III

Preliminary Results of Agricultural Research on Compost

Corn Grain Research Project, Johnson City, Tennessee. This project involves the use of refuse-sludge compost in the growth of corn on agricultural soils. Application rates in fall or spring ranged from 0 to 200 tons per acre. The purpose of such a range in application rates was to determine the soil and crop improvement resulting from various amounts of compost and the maximum amount of compost that can be applied before the effect is adverse or deleterious. The fall applications of 4, 8, 50, 100, and 200 tons per acre of unscreened compost were made in November 1968, and plowed under shortly thereafter. Spring applications were made in April 1969, and disked into the soil. Nitrogen rates of 80 and 160 lb per acre were also compared alone and with 8 tons of spring-applied compost. There was a total of 52 test plots with each plot receiving phosphorus and potassium at rates adequate for maximum plant growth. The corn was planted on May 2, 1969.

There was a slight reduction in germination on the plots that received the three highest rates of compost (50, 100, and 200 tons per acre) with the lowest percentage germination coming on the 200-ton-per-acre rate. One factor that contributed to this reduction in germination was the inability because of the bulkiness of the compost to prepare a firm seedbed, especially on the plot receiving the 200-ton-per-acre rate. Other factors that affected the overall number of plants on all

plots were (1) the crop was damaged somewhat by birds, (2) extremely cool temperatures occurred during the germination period, and (3) there was also some damage caused by hail.

Nitrogen deficiencies developed in all plots that did not receive supplemental inorganic nitrogen. Early growth was extremely poor on the plots that received the three heaviest compost applications; however, toward the middle of the growing season, the corn on these plots began to make some progress. The first noticeable growth response came on the 50-ton-per-acre treatment followed in sequence by the 100- and 200-ton-per-acre rates. The final results indicated that these three treatments gave favorable results when compared to the plots receiving the 80- and the 160-lb-per-acre nitrogen treatments with no compost. It was also noted that the corn on the 200-ton-per-acre plot remained green longer than any other treatment. These early results would seem to indicate that the heavy application of compost had a definite effect on the amount of nitrogen being released to the soil in a form readily available to the plant, the heavier the application of compost, the longer it took for the corn to respond. It was approximately 7 months from the time the compost was plowed under in the 200-ton-per-acre treatment before there was any visual growth response that could be considered a normal growth pattern.

Final yield results of this first year observation showed that grain yields increased from 55 bushels per acre without nitrogen or compost to 76 bushels with 80 lb of nitrogen or with 100 tons of compost and to 90 bushels per acre with 160 lb of nitrogen plus 8 tons of compost.

Four to 8 tons per acre of compost alone resulted in slight, if any, increase in corn yields.

The value of compost on corn in terms of increased yields ranged from a (minus) -\$1.75 per ton on spring applied compost at a rate of 4 tons per acre with no supplemental nitrogen to a (plus) +\$3.18 per ton on spring applied compost at a rate of 8 tons per acre with 160 lb of supplemental nitrogen per acre. The value of compost when applied at a 200-ton-per-acre rate with no supplemental nitrogen was \$.08 (8 cents) per ton, however, this does show that large amounts of compost can be utilized on agricultural soils with positive results. Additional studies will determine the residual effect of high rates of application of compost over a period of years.

It was apparent during the first year of testing that a combination of compost plus inorganic fertilizer produced greater yield than either compost or fertilizer alone. The response from the corn on the plot that received compost plus 160 lb of nitrogen was evident throughout the growing season as the corn stalks appeared greener and stronger than stalks from other plots. When inorganic fertilizer was used without compost, the yield on the 80 lb per acre of nitrogen and the 160 lb per acre of nitrogen treatments was approximately the same which would indicate that the excess over 80 lb per acre of nitrogen was not efficiently utilized by plant uptake. This situation can be partly attributed to the relatively small number of plants per plot; however, when 8 tons per acre of compost was used in conjunction with 160 lb per acre nitrogen, there was an approximate 20 percent increase in yield over the 160 lb

per acre of nitrogen alone or the 8 tons per acre compost with 80 lb per acre of nitrogen. It would appear that the compost had somewhat of a synergistic effect on the inorganic nitrogen since it is very doubtful that 8 tons of compost per acre would supply enough nitrogen or moisture to bring about such an increase in yield.

There are some preliminary conclusions drawn from 1 year of testing. More valid information can be gathered from results obtained from 4 or 5 years of continuous testing. Table 1 presents a summary of yield data obtained from corn research at Johnson City during 1969.

Use of Compost for Sorghum Production. (Experiment 56, National Fertilizer Development Center, Muscle Shoals, Alabama.)

Yields of dry sorghum forage increased from 5 tons/A without compost or N to 7.5 tons with 82 tons of compost and to 8 tons with 160 lb of applied N. Thus, the value of the compost in terms of the N it supplied was very low. Less wilting during dry periods on plots receiving large applications of compost indicated that it increased the moisture holding capacity of the soil. The results also indicate that agricultural land will accept large amounts of compost with small positive yield effects.

Procedure. Unground compost from Johnson City, Tennessee, was applied in fall, spring, or combination applications for Funk's 101F forage sorghum at total rates ranging from 6 to 82 tons per acre. Fall-applied compost was plowed under shortly after application, while spring applications were incorporated by disking. Compost rates were compared with 80 to 160 lb/A of N, with three treatments supplying both N and compost and a check treatment with no N or compost.

TABLE 1

Compost Experiment--Johnson CityEar Corn Yields - Acre Basis

1969

<u>Treatment</u>	<u>Number of Stalks</u>	<u>Ear Corn</u>	
		<u>Pounds</u>	<u>Bushels</u>
1 - None	8230	3570	55
2 - 80 N	8470	4960	76
3 - 4T-Spring	8230	3235	49
4 - 160 N	8230	4750	73
5 - 8T-Spring	8710	4325	66
6 - 8T-Fall	8230	3810	58
7 - 4T-Fall	7745	3900	60
8 - 8T-Spring + 80 N	8710	4900	75
9 - 8T-Spring + 160 N	8470	5870	90
10 - 8T-Fall	8230	3780	58
11 - 50T-Fall	7745	4535	69
12 - 100T-Fall	7745	4990	76
13 - 200T-Fall	6775	4295	66
L.S.D., 5% Level	N.S.	855	13

Compost contained 40% moisture; application rates are on a dry basis. N was applied in spring as ammonium nitrate. Pounds of ear corn are as harvested (Av. of 14.5% moisture); bushels are on the basis of 15.5% moisture (70 pounds per bushel). The corn variety was Funk's G-5757.

Chemical components in the compost were as follows (% , dry weight basis):

<u>Application Time</u>	<u>N</u>	<u>P</u>	<u>K</u>	<u>C</u>	<u>Ca</u>	<u>Na</u>	<u>Mg</u>	<u>S</u>	<u>Zn</u>
Fall 1968	1.2	0.24	0.80	34.2	3.6	0.49	0.49	0.4	0.13
Spring 1969	1.3	0.40	0.96	26.8	6.4	0.82	0.87	0.4	0.15

P and K were applied at rates thought to be adequate for maximum plant growth. Forage sorghum was planted on April 23, and harvested on July 28 and October 15.

Results and Discussion. Forage yields, percentages, N content and N uptake are given in Table 2. Total yields of dry sorghum forage increased in a generally linear fashion with higher compost rates. Yields ranged from 10,814 lb/A on the check plot to 15,032 with 82 tons of compost/A. In contrast, 80 lb of N produced 13,850 lb of forage, while 160 lb produced 16,384 lb/A. The highest yield, 18,823 lb/A., was produced by 160 lb of N and 40 tons of compost. Forty tons of compost produced as much forage as 80 lb of N, but no compost rate was as good as 160 lb of N. In all cases, compost plus N produced more forage than either material alone.

At the first harvest, N contents of the forage were much higher with N alone than with compost alone, but differences were small at the second harvest. N uptake for similar yields was less from compost-treated than from N-fertilized plots. The N content and uptake data indicated that this was probably due largely to luxury uptake of N on fertilized

TABLE 2

Response of Forage Sorghum to Applications of Compost and N

Compost Fall	Rate Spring	Tons/A	N Rate Pounds/A	Dry Forage, Pounds/A			N Content, %			N Uptake, Pounds/A			Increase over no N or compost
				Cut 1	Cut 2	Total	Cut 1	Cut 2	Total	Cut 1	Cut 2	Total	
0	0	0	0	8155f	2659e	10814g	.63	1.08		51.3	29.2	80.4g	-
0	0	0	80	10205c	3643de	13850de	1.08	.91		109.9	33.7	143.6d	63.2
0	6.2	0	0	8696ef	2943e	11640fg	.66	.95		57.3	27.9	85.1g	4.7
0	0	0	160	11306f	5076b	16384b	1.33	1.13		150.6	58.1	208.8ab	128.4
0	12.4	0	0	9214de	3434e	12649e	.71	1.03		65.5	36.0	101.5f	21.1
8	0	0	0	8736ef	3158e	11895fg	.65	1.00		55.9	31.5	87.3fg	6.9
4	6.2	0	0	9035def	3411e	12447f	.68	.90		61.6	30.7	92.3fg	11.9
0	12.4	80	80	11717b	4138cd	15856bc	1.10	.99		128.0	41.0	169.0c	88.6
0	12.4	160	160	12158ab	5729ab	17888a	1.15	1.06		139.1	61.0	200.1b	119.7
8	12.4	0	0	8871def	3531d	12403f	.72	1.06		63.7	37.3	101.0f	20.6
16	24.8	0	0	9483cde	4340c	13825de	.78	.97		73.2	42.0	115.3e	34.9
32	49.6	0	0	9773cd	5258b	15032cd	.88	1.11		86.4	55.1	141.4d	61.0
16	24.8	160	160	12670a	6151a	18823a	1.20	1.11		150.0	67.4	217.4a	137.0

Note: In all yield tables means with the same letter are not significantly different at the 5 percent level.

plots. Observation of the sorghum during dry periods indicated that compost contributed some moisture holding capacity to the soil. There was always less leaf curling on plots treated with the higher compost rates.

A slight stand reduction occurred on plots receiving 50 tons in the spring. It was not possible to incorporate this amount of compost well enough to provide the firm seedbed needed for good germination.

Value of compost per ton in terms of its contribution to yield increase was lower with increasing application rates. Dry matter yield increases per ton of compost ranged from 255 lb at the 6 ton rate to 52 lb at the 80 ton rate. The yield contributions were similar with and without N additions. Assuming that sorghum forage is worth \$10 per ton on a green weight basis, compost was worth approximately \$2.20 per ton at 8- to 12-tons-per-acre application rates and approximately \$1.10 at rates of 20 tons per acre or more. If, on the other hand, the value is based on the amount of N needed to give equal yield, it was worth about \$0.13 per ton.

As with the bermudagrass experiment (No. 57), this experiment showed that large amounts of compost can be disposed of by application on agricultural land without apparent yield reductions.

The compost used in these two experiments was unground and contained plastic, both film and dense type, fairly large pieces of glass and metallic waste. It would have been completely unsuitable for application to grazing or hay land and was objectionable from an aesthetic viewpoint for most surface application uses.

Evaluation of Compost on Common Bermudagrass. (Experiment 57, National Fertilizer Development Center, Muscle Shoals, Alabama.)

Yields of bermudagrass forage increased from 2.9 tons with no compost or N to 3.5 tons with 12 tons per acre of compost. The corresponding yield with 160 lb per acre of N/A were 5.0 tons without compost and 5.2 tons with 12 tons per acre of compost. The increases for compost were of insufficient value to pay for application costs.

Procedure. Compost was topdressed on common bermudagrass sod in November 1968, at rates of 0, 4, 8, and 12 tons per acre. In 1969, N rates of 0 and 160 lb per acre were superimposed on plots of each compost rate. Half the N was applied in April and half after the second harvest. The grass was cut four times. Results are presented in Table 3.

Results and Discussion. Without added N there was a slight but consistent increase in total yield with increasing compost rates ranging from 5,772 lb per acre with no compost to 7,045 lb with 12 tons per acre of compost. Where N was applied the 4-ton-per-acre compost application resulted in a slight reduction in yield, and 8 and 12 tons per acre in slightly increased yield. The increase was greater with 8 than with 12 tons per acre of compost.

Although there were inconsistencies in yield response to compost, the 8-ton-per-acre rate at both N levels resulted in approximately 900 lb additional forage per acre. At \$25.00 per ton as the market value for bermudagrass hay, this compost would have been worth \$1.25 per ton spread on the field. This would hardly pay spreading costs let alone production and transportation expense. However, this data does indicate that it might be possible to dispose of significant amounts of compost by spreading it on grasslands providing that it did not contain solid material harmful to livestock.

TABLE 3

Response of Common Bernudagrass
To Compost and Nitrogen, 1969

<u>Treatments</u>		<u>Forage harvested, pounds</u>				
<u>Compost, T./A</u>	<u>N, Lbs/A</u>	<u>Cut 1</u>	<u>Cut 2</u>	<u>Cut 3</u>	<u>Cut 4</u>	<u>Total</u>
4	160	2899	2177	1731	3290	10,098a
4	0	1663	1826	504	2644	6,639bc
8	160	3017	2533	2031	3590	11,172a
8	0	2025	1943	574	2211	6,755bc
12	160	2529	2696	1845	3444	10,515a
12	0	1628	1992	721	2702	7,045b
0	160	3156	2048	1961	3146	10,312a
0	0	1732	1436	535	2069	5,772c

Note: In all yield tables means with the same letter are not significantly different at the 5 percent level.

JOINT USEPA-TVA COMPOSTING PROJECT
JOHNSON CITY, TENNESSEE

Volume II
with Operational Data
October 1969-June 1971

This volume was prepared by CARLTON C. WILES
under the direction of CLARENCE A. CLEMONS

VOLUME II

JOINT USEPA-TVA COMPOSTING PROJECT, JOHNSON CITY, TENNESSEE WITH OPERATIONAL DATA October 1969 - June 1971

On February 15, 1966, the U.S. Public Health Service, the Tennessee Valley Authority (TVA), and the city of Johnson City, Tennessee, signed a cooperative project agreement to construct and operate the "Joint USPHS-TVA Composting Project, Johnson City, Tennessee." This project was undertaken as a joint research and demonstration project in windrow composting of municipal solid waste and sewage sludge. Plant operations were initiated on June 20, 1967.

Details of project background and site location, plant design and construction, plant operation and process, and details of important investigations conducted prior to October 1969, are discussed in Volume I.

Volume II supplements the first progress report. Although it provides a record of plant operations covering the period October 1969 to June 30, 1971, the primary purpose is to present results of compost utilization demonstrations and research projects which were in preliminary stages at the time of the first report. For the purpose of continuity, plant operations are discussed prior to the compost utilization work.

PLANT OPERATIONS

Technical Staffing

For two years, the Division of Research and Development, Bureau of Solid Waste Management,* staffed the project with a project engineer, a staff sanitary engineer, a staff chemist, a staff microbiologist, and a staff assistant. This staff was responsible for completion of the studies reported in the Volume I report. Later the staff was reduced to a project engineer, a staff assistant, and two part-time technicians. Staffing during the last year consisted of a project engineer, an administrative assistant, one part-time technician, and one part-time clerk-typist.

James C. Duggan, Agriculturist, (TVA) served as resident agriculturist with responsibility for establishing and coordinating compost utilization demonstrations and research projects.

The plant TVA operating staff usually consisted of one foreman, one assistant foreman, two equipment operators, three truck drivers, two maintenance mechanics, and four laborers.

Administrative supervision of the TVA operating and research staff and administrative services, accounting, etc., were performed by nonresident staff.

*At that time, the Bureau was part of the U.S. Public Health Service. The PHS solid waste management program became part of the U.S. Environmental Protection Agency in December 1970.

Plant Process

The plant was designed for a nominal capacity of 60 tons per day for an eight-hour shift. Details of the plant, the process, and equipment specifications were discussed in Volume I.

Important changes during the period covered by Volume II involved the cessation of sewage sludge dewatering at the plant because of mechanical difficulties with the Permutit Dual Cell Gravity (DCG) Solids Concentrator. Because of these problems and the fact that the machine did not have capacity to dewater all sludge produced at the Johnson City plant, a decision was made in July 1969 to cease the processing of sludge in this manner.

Subsequently, in December 1969, the drum mixer for mixing the ground refuse and sewage sludge was removed and was replaced with a conveyor. It could be easily reinstalled should future plant operations require dewatering of sewage sludge in the plant. Thereafter, sewage sludge was dewatered at the treatment plant, hauled to the compost plant and added directly to the windrows by payloader. Mixing by the windrow turner was done successfully and this method was continued through the remainder of the project period. However, such a procedure might prove laborious or uneconomical in a municipal operation.

One problem with the mixing drum was that the throat was too small to accept the flow of refuse from the hammermill when operating.

at full capacity. Had the mixer been reinstalled, modifications to correct this would have been necessary.

During the period of research reported herein, additional screening equipment was fabricated and installed. The fabrication and installation are discussed in a subsequent section.

Processing Data

Raw Refuse. Refuse received and processed throughout the project amounted to 33,503 tons for 916 processing days and averaged 37 tons per day. The average for the June 1967 to September 1969 period was 34 tons per day. The average increased to 41 tons per day during the period October 1969 to June 1971. As would be expected, the amount of refuse received at the plant varied with seasons (Figure 1).

The main reason for the increase in the amount of refuse received during the current report period as compared to the first, was the acceptance of refuse from sources other than Johnson City. In May 1970, the PHS, TVA, and Johnson City agreed to permit acceptance of refuse from the Rural Sanitation Service and the Washington County Utility District. This accounted for much of the higher quantity shown on Figure 1 for 1970 when compared to earlier years.

The Rural Sanitation Service provides weekly refuse collection service to approximately 800 rural households (estimated 4,000 persons) in Carter County, Tennessee.² The Washington County Utility

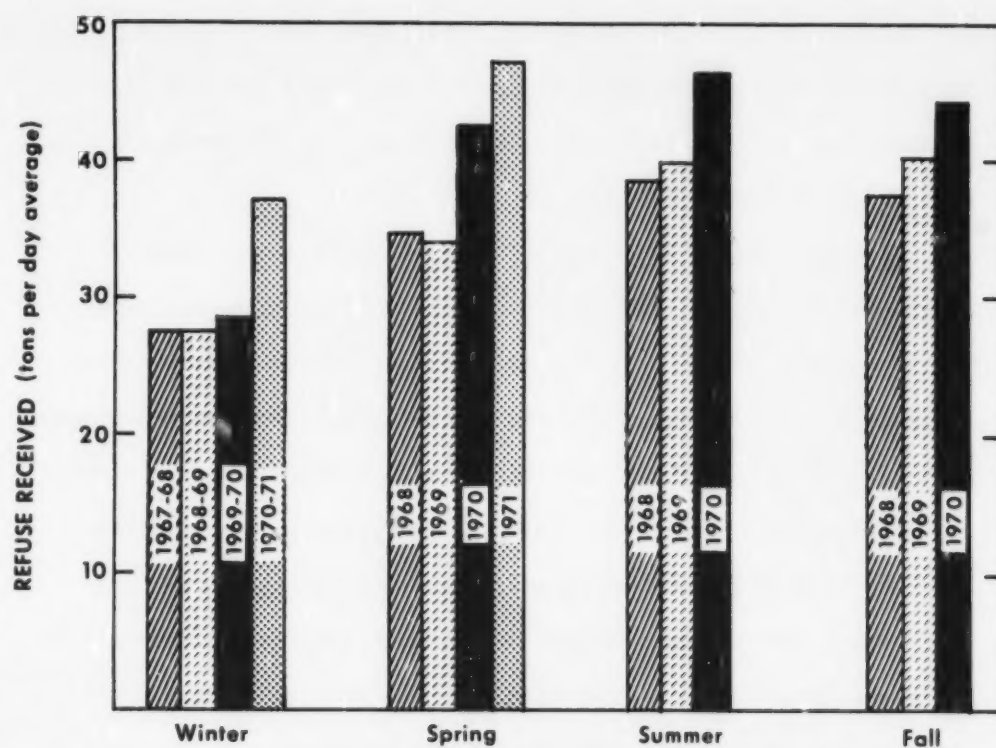


Figure 1. Seasonal variation in quantity of refuse received.

District services both rural customers (Washington County, Tennessee) and some Johnson City residents desiring supplementary refuse collection service.

Based upon the amount of refuse delivered to the project from these sources and the estimated persons served, a refuse collection rate of 3.0 pounds per person per day was estimated for residents served by the Rural Sanitation Service; and 2.1 pounds per person per day for residents served by the Washington County Utility District. This compares to an estimated 2.0 pounds per person per day for Johnson City in 1968 (Volume I). This latter figure apparently has not changed significantly.

Screened Compost Production. In an earlier study, compost production was established at approximately 50 percent (wet weight) of the incoming refuse. During this period, screening resulted in a higher proportion of rejects and compost production was determined over a 12-month period by weighing incoming refuse, screened compost, and total rejects (Table 1). Based on the figures thus obtained, screened compost production is estimated to have been 44 percent (wet weight) of incoming refuse. The reason for the difference between the production rate reported from the earlier study and the present rate is that the earlier rate did not take into account the rejects generated by the screening process.

Rejects. During the same production period mentioned above, picking and sorting rejects amounted to 24 percent, i.e., slightly

TABLE 1
PRODUCTION OF SCREENED COMPOSTED REFUSE AND REJECTS

Month	Raw Refuse* Received (Tons)	Composted Refuse*, Screened Product (Tons)	Rejects		Total
			Pick	Screen	
July 70	986	305	236	146	382
Aug 70	979	248	218	92	310
Sep 70	960	348	218	156	374
Oct 70	817	375	204	154	358
Nov 70	832	278	207	120	327
Dec 70	194	176	42	44	86
Jan 71	803	221	186	100	286
Feb 71	720	25	145	10	155
Mar 71	1040	8	232	7	239
Apr 71	1071	300	279	144	423
May 71	956	235	231	140	371
June 71	734	318	203	145	348
Jul 71		456		176	176
Aug 71		528		196	196
Sep 71	—	<u>582</u>	—	<u>128</u>	<u>128</u>
TOTAL	10,092	4403	2401	1758	4159

*Wet weight basis. Estimates of dry weights based upon random moisture analysis are provided in later sections.

less than the 27 percent average during the June 1967 to September 1969 reporting period. The screening operation produced additional rejects not removed during the earlier study during which the 50 percent compost production rate was established. These screening rejects amounted to 17 percent of incoming refuse.

Plant Maintenance

During the term of the project, only one major shutdown was scheduled for the purpose of performing plant maintenance. During December 1970, the following items were completed:

1. Installation of new rollers for the plate conveyor in the receiving hopper.
2. Installation of new rollers for the plate conveyor of the leveling gate.
3. Installation of new belt skirts on plant conveyors.
4. A support column was removed from the receiving building and replaced with a horizontal beam to provide easier access to the hopper.
5. A new drum was constructed for the windrow turner to replace the old drum which was extensively worn. As indicated in the first report, the windrow turner continued to experience mechanical problems resulting in short periods of downtime.
6. All other equipment was thoroughly checked and cleaned. All buildings were cleaned and repaired where needed.

Other maintenance requirements were discussed in the first progress report.

Updated Cost Data

Cost Accounting. A system of cost accounting for plant operations and maintenance was developed initially to facilitate systematic reimbursement to TVA. Plant operations and activities were divided into various categories or units with each receiving an account number. Classification of expenditures by functions or purposes was accomplished through the applicable account classifications. Cost data obtained from these monthly, quarterly, and year-end financial statements of operations were reported and used to project costs to other windrow composting plants.^{1,3} This discussion will provide additional data with respect to actual cost of project operations.

Capital Costs. The total construction cost for the plant, including modifications made since startup, was \$960,452. Mobile equipment, such as trucks, front end loaders, and the windrow turner used in routine operations cost another \$61,280. Costs for the regrinding and screening include \$15,021 for procurement and installation of the zig-zag air classifier, which has not been used in routine processing. Approximately \$61,000 was expended for laboratory research instruments, tools, office equipment and miscellaneous items not needed in routine compost plant operations. Table 2 itemizes these costs.

TABLE 2
CONSTRUCTION AND EQUIPMENT COSTS FOR THE PHS-TVA
WINDROW COMPOSTING PLANT ^{1/}

	Construction or Installation	Equipment and/or Materials	Engineering Design	Total
Site improvements	78,060		10,032	88,092
Buildings				
Receiving building	90,382		13,982	104,364
Process building	142,742		21,800	164,542
Office and laboratory	40,954		7,883	48,837
Curing and drying shed	44,193		7,111	51,304
Receiving machinery and equipment				
Hopper conveyor and leveling gate	12,644	24,866	5,800	43,310
Scale	8,059	4,266	1,112	13,437
Processing				
Elevating conveyor (sorting belt), w/magnetic separator	23,608	11,667	6,828	42,103
Reject hopper	7,119		965	8,084
Rasp machine (grinder)	7,477	51,160	9,380	68,017
Hammermill (grinder)	8,603	17,960	3,672	30,235
Chuting	8,153	1,838	1,570	11,561
Conveyors	9,902	8,930	2,418	21,250
Air compressor	741			741
Sludge filter and appurtenances, including sludge holding tank	2,300	23,273	4,320	29,893
Ground refuse-sludge mixer	2,760	6,528	1,490	10,778
Sludge piping	13,760	2,699	2,700	19,159
Power and control system	36,182		5,820	42,002
Bucket elevator	1,409	6,000	1,282	8,691
Loading bin and chute	11,603		1,324	12,927
Composting field, site preparation and waterlines	28,793		9,901	38,694
Regrinding and screening, including conveyors	73,976 ^{2/}	25,664		99,639
Gasoline dispensing installation	1,755	788	253	2,796
Subtotal	655,171	185,638	119,643	960,452
Mobile equipment ^{3/} (trucks, front end loaders and turner)		61,280		61,280
Small equipment		60,727		60,727
Subtotal		122,007		122,007
Total	655,171	307,645	119,643	1,082,459

1. All cost rounded to nearest dollar.
2. Includes installation, construction materials, and design costs.
3. Includes laboratory research instruments, tools, office equipment, etc.

Operating Cost. The Statement of Operations, Division of Reservoir Properties, TVA, provided actual operating cost data for the composting plant. Appendix I provides FY 70 and FY 71 costs in the June 1970 and June 1971 statements.

Based on these data, the actual operating cost in FY 70 for processing 8,687 tons of refuse (222 days) was \$22.91 per-ton-of-refuse processed. The processing cost in FY 71 was \$19.70 per-ton-of refuse for processing 10,092 tons (232 days). These costs no doubt reflect the research, development, and demonstration nature of the project. Another reason was the lack of a sufficiently large input of refuse to permit processing at full capacity. Volume I discussed this in some detail and provided extrapolation to full capacity and to larger size windrow composting plants.

An estimated 37 percent of the FY 70 operating costs could be directly charged to special projects. If costs incurred for such items as fabrication of screening equipment, installation of an air classifier (and other special projects) are substrated from the FY 71 expenditures, the cost per-ton-of-refuse processed would drop to \$18.18.

The following reimbursements were made to Johnson City for added hauling costs and truck use. These are not included in the above.

<u>Year</u>	<u>Cost in Dollars</u>	
	<u>Operations</u>	<u>Truck Use</u>
FY 67	22.29	-
FY 68	4322.40	4094.09
FY 69	5373.41	3070.56
FY 70	3556.64	4094.08
FY 71	<u>4060.53</u>	<u>9201.27</u>
Total	17,335.27	20,460.00

Listed below is salary information for the TVA plant operating complement.

	<u>Annual Salary*</u>		
	<u>1969</u>	<u>1970</u>	<u>1971</u>
Foreman	\$9300	\$9835	\$10555
Assistant Foreman	7740	8220	8820
Equipment Operator	7050	7505	8075
Truck Driver	6885	7310	8110
Maintenance Mechanic	8490	8965	9610
Laborer	6100	6440	6840

Plant Income. Compost produced during the project was not sold, nor was salvaging of potentially salable materials practiced. However, with respect to the dollar value of compost, some users of the compost (TVA demonstrations) in high value money crops,

*The salaries are for an 8-hour day, with 8 paid holidays in 1969, and 20 paid vacation days. Holidays increased to 9 in 1970. Added benefits amount to approximately 17 percent of the salaries. Overtime is paid at the rate of time and one-half on regular workdays and double time on holidays.

placed an average value of \$5.80 per ton on the compost produced at Johnson City. This information was obtained during a survey conducted by the TVA Agriculturist.⁴

SPECIAL PROJECTS

Although major project investigations were completed and the staff reduced during the period covered by Volume I, the project continued to be utilized for a number of special projects.

Grinding Study

In 1970, the Bureau of Solid Waste Management (now the Office of Research and Monitoring) initiated a research program designed to obtain information relative to the development of better methods for comminuting solid waste. The first project in this research program was to study the Gruendler hammermill installed at the USPHS-TVA Composting Project, Johnson City, Tennessee. Primarily an activity of the Waste Handling and Processing Branch, the study utilized this active project's refuse supply, equipment, facilities, and labor force.

The primary objective of this first grinding study was to determine the relationship between power input and grate opening size of the shredder. Three different grate openings (2-inch, 4-inch, and 6-inch) were tested. Statistical considerations indicated that these would be sufficient to identify linear and quadratic effects of the power input versus grate opening size relationship.

The study lasted 12 weeks and involved one experiment each week.

Data recorded for each experiment included:

1. Weight of refuse to be processed.
2. Final moisture content of the refuse.
3. Initial and final weight of the hammers.
4. Power input.
5. Operation personnel - man-hours.

A set of hammers wears considerably during the comminution of raw refuse. Therefore, after each experiment the hammers were removed, weighed, and then rebuilt. A rebuilt set was then placed back into the mill along with the appropriate set of grates. Rebuilding and conditioning of the worn hammers was accomplished by on-site TVA personnel.

Description of the Shredder. The shredder is a Gruendler, Model 48-4, swing hammermill. This mill is driven by a direct-drive 250 horsepower Allis Chalmers electric motor rotating at 1,150 revolutions per minute. Forty-four hammers, each weighing approximately 22 pounds, are distributed on four horizontal shafts. Grate openings can be varied by changing the distance between the steel bars beneath the breaker plate. The theoretical capacity of this hammermill and motor combination is 12 tons per hour of shredded refuse using 1.5-inch grate openings.

Summary of Results. The results of this study indicated that there is an inverse non-linear relationship between power input and grate spacing. As the grate opening decreased, power consumption increased at an exponential rate. A similar relationship between power input and hammer wear was not established.

Tables 3, 4, and 5 present data obtained from this investigation. Details of experimental procedures, maintenance requirements, operational data, and test results are available.⁵ Results and experience obtained from this study were used to develop broader and more meaningful grinding research projects.

Comparison of the Compost
from Hammermill and Rasper Processed Refuse

During the grinding study, the quality of compost being produced with hammermill ground refuse was suspected by various observers as being inferior to that produced with rasper ground refuse. This premise was based on the physical appearance of the compost produced. A series of tests was devised to obtain experimental data to either confirm or refute the subjective observations that the larger particle sized material from the Gruendler hammermill did not compost as well as that from the Dorr-Oliver rasper.

Two windrows of material ground with each grate spacing (2-inch, 4-inch, and 6-inch) from the hammermill and two windrows of rasper ground material were selected for testing. A windrow of material

TABLE 3
WEIGHT LOSS PER HAMMER SET
(44 Hammers Per Set)

Experiment Number	Weight of Hammer Set		Weight Loss Pounds	Refuse Comminuted Tons	Grate Bar Spacing Inches	Tons of Material Per lb. Loss
	Initial	Final				Tons/lb.
	Pounds	Pounds				
1	924.50	916.50	8.00	137.70	2.0	17.2
2	923.00	914.00	9.00	149.65	4.0	16.6
3	928.00	915.50	12.50	138.10	2.0	11.1
4	924.00	914.00	10.00	128.90	4.0	12.9
5	925.50	918.50	7.00	105.30	4.0	15.0
6	927.00	915.75	11.25	133.00	6.0	11.8
7	924.00	915.75	8.25	141.55	4.0	17.2
8	924.00	916.00	8.00	126.90	6.0	15.9
9	924.00	915.50	8.50	132.05	4.0	15.5
10	924.00	916.00	8.00	154.00	6.0	19.3
11	922.00	914.00	8.00	157.10	4.0	19.6
12	921.00	912.00	9.00	153.10	2.0	17.0
			(Pounds)	(Tons)	Avg. Ton/lb.	
TOTAL			107.50	1,675.35	15.42	

TABLE 4
POWER CONSUMPTION DURING GRINDING EXPERIMENT

Experi- ment No.	Grate Opening (in.)	Wt. of Refuse Comminuted (Tons)	Total Operating Time (Hour)	Total Power (KWH)	No Load Power (KWH)	Net Power (KWH)	Total Power KWH/ Ton	Net Power KWH/ Ton	Average Moisture Content (%)*
1	2	137.7	27.5	1216	165	1051	8.83	7.63	40.8
2	4	149.7	28.5	831	171	660	5.91	4.69	40.8
3	2	138.1	26.0	1120	156	964	8.11	6.98	36.6
4	4	128.9	26.1	768	157	611	5.96	4.74	41.8
5	4	105.3	26.5	672	159	513	6.38	4.87	43.7
6	6	133.0	26.1	576	157	419	4.33	3.15	33.4
7	4	141.6	26.0	672	156	516	4.75	3.64	38.3
8	6	126.9	26.3	544	158	386	4.29	3.04	34.6
9	4	132.1	26.0	832	156	676	6.30	5.12	28.2
10	6	154.0	31.9	640	191	449	4.16	2.91	31.8
11	4	157.1	31.3	928	188	740	5.91	4.73	28.8
12	2	153.1	31.0	1408	186	1222	9.20	7.98	28.0

*After grinding

TABLE 5

COST OF MATERIAL GROUND
(DOLLARS)

Experi- ment No.	Grate Opening In.	Weight of Refuse Ground Tons	Cost to Operate System	Hammer and Grate Changes		Hammer Build-up Cost	Depreci- ation on System	Basic Cost/ Ton	Est. Misc. Cost/ Ton	
				Cost	Cost				Cost/ Ton	Cost/ Ton
1	2"	137.70	320.52	82.92		133.60	56.81	4.31	0.24	4.55
2	4"	149.65	315.40	58.16		138.35	56.81	3.80	0.24	4.04
3	2"	138.10	319.27	81.19		119.50	56.81	4.18	0.24	4.42
4	4"	128.90	314.69	52.17		101.85	56.81	4.08	0.24	4.32
5	4"	105.30	313.45	35.04		87.15	56.81	4.68	0.24	4.92
6	6"	133.00	312.20	83.58		74.60	56.81	3.96	0.24	4.20
7	4"	141.55	313.45	59.95		68.25	56.81	3.52	0.24	3.76
8	6"	126.90	311.78	40.91		60.90	56.81	3.71	0.24	3.95
9	4"	132.05	315.53	42.74		63.90	56.81	3.63	0.24	3.87
10	6"	154.00	369.56	36.98		59.35	56.81	3.39	0.24	3.63
11	4"	157.10	373.30	54.97		87.30	56.81	3.64	0.24	3.88
12	2"	153.10	379.54	57.30		89.55	56.81	3.81	0.24	4.05

Average for 2" = \$4.32
 Average for 4" = \$4.09
 Average for 6" = \$3.91

ground by the hammermill, using 2.5-inch perforated plates, was added after completion of the grinding study. Data collected included temperatures during composting, C/N analysis of samples taken at the end of the composting cycle and of the various screening fractions, and material balances for each windrow as it was screened. While it would have been desirable to completely monitor the C/N ratio and moisture throughout the composting cycle, this was not possible because the tests were not initiated until near the end of the grinding study. Temperature data for each windrow were available from routine plant control data.

The yield (tons of screened product) of compost from the rasper ground material was less in relation to the amount of material fed to the screen (8.6/20.4) than for hammermill ground material (i.e., 9.1/15.0 for 4-inch grate spacing). In addition the processing rate was less; 2.0 tons per hour for rasper material compared to 2.1 to 2.4 tons per hour for hammermill material. More important, however, is the observation that the C/N for the product passing the screen was significantly higher (38) for the rasper ground material than for the hammermill material (29-32). If the two tons of rasper material that are unaccounted for were assumed to have passed the screen the difference in production would have been less, but still appreciable (Table 6).

Examination of the average windrow temperature profiles for each test material does not reveal any significant differences

TABLE 6
COMPARISON OF COMPOST PRODUCED FROM RASPER GROUND REFUSE
TO COMPOST PRODUCED FROM HAMMERMILL GROUND REFUSE

Grinding Process	Grate Opening In.	Composted Refuse		Screened Product		Rejects	
		Tons*	C/N	Tons	Tons/Hr*	Tons*	C/N
Hammermill	6"	14.6	38	9.7	2.6	4.8	74
Hammermill	4"	15.0	48	9.1	2.1	6.0	60
Hammermill	2"	23.2	41	13.4**	2.4	7.5**	54
(Perf Plate) Hammermill	2-1/2" (Perf Plate)	19.8	36	11.4	2.4	8.5	64
Rasper	1-1/4" (Perf Plate)	20.4	45	8.6**	2.0	9.8**	74
Special***		11.9	25	10.5	5.2	1.8	61

*Dry weight basis.

**Losses assumed to have occurred during processing.

***Windrow placed back on field for additional composting.

among the various materials (Figure 2). A drop in the temperature of the 6-inch grate hammermill material during the second half of the composting cycle indicated a possible lack of moisture. This tends to confirm an observation made during the grinding study that the larger sized material failed to accept and absorb water as readily during processing and composting as did the smaller sized materials.

The data would seem to refute the subjective observation that the compost from hammermill processed refuse is inferior to compost from refuse processed through the rasper. Observations that the larger sized material presents a less pleasing appearance in the windrow and causes a bigger housekeeping problem than does the smaller material, remain valid.

Refuse Baling Project

In January 1970, the USPHS-TVA Composting Project's facilities, equipment and labor force were used in a refuse baling project. A cooperative effort among various sections of the Bureau of Solid Waste Management, the project objective was to produce bales of solid waste suitable for use in sea disposal experiments.

Since details of the sea disposal experiments are not germane to this report they are not given herein. With respect to the baling operation at Johnson City, 180 tons of refuse were processed

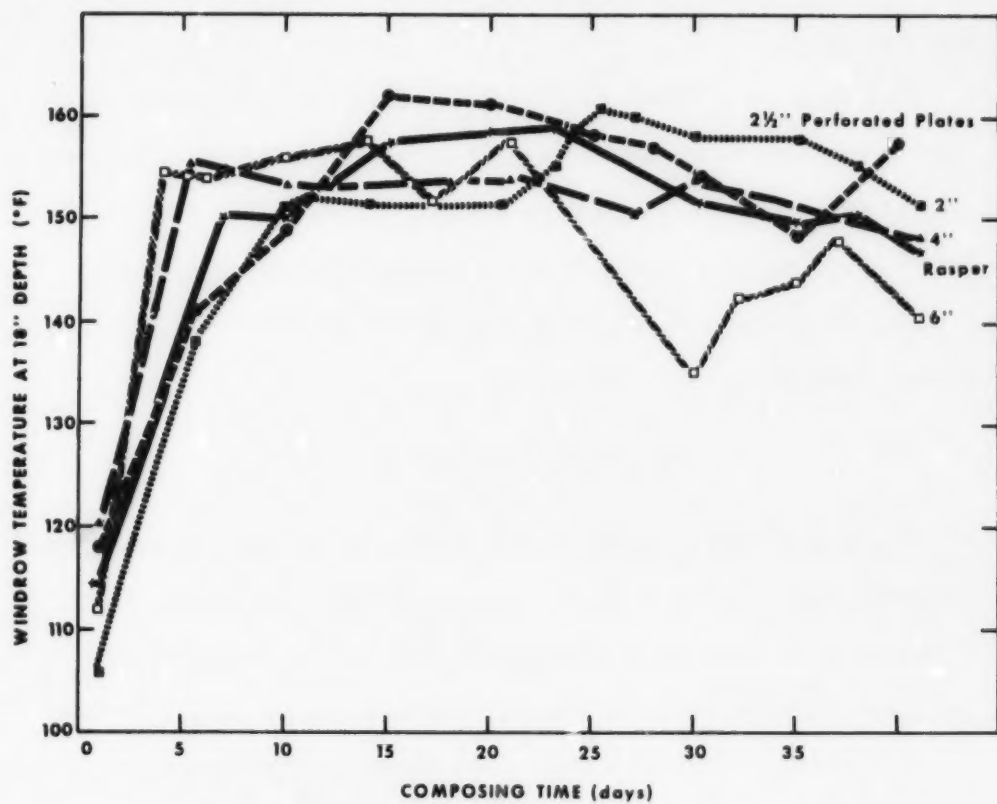


Figure 2. Temperatures at the 18-inch depth of the grinding study test windrows reveal no significant differences among the various materials.

through the Gruendler hammermill and were baled into 83 bales. The bales averaged 1.6 tons each, and 31 of the 83 bales had a density of 64 pounds per cubic foot or more.

This undertaking possibly represents one of the largest production runs on baling solid wastes ever performed hitherto in the United States. During times when snow covered the ground, large flocks of birds, probably in search of food, attacked the bales and caused extensive damage to them. This interesting observation indicated the possibility of this occurring during baling operations if this technique becomes part of landfill or solid waste management processes. Appendix II provides details of the baling experiment.

Composting Leaves with Refuse

During December 1970, approximately 46 tons of leaves (primarily from hardwood trees) were received from Johnson City. Because of the scheduled plant shutdown for maintenance, the leaves helped to fill some windrow spaces on the field and provided an opportunity to obtain preliminary information relative to the composting of leaves with municipal refuse. It was decided to explore the feasibility of disposing of leaves directly through the routine municipal refuse composting cycle without processing them by grinding. However, one batch of leaves was ground.

Four windrows with various combinations of leaves and refuse were placed on the field. Samples were taken from the windrows at 5-, 10-, 20-, 30-, 40-, and 50-day intervals, and the C/N were determined at the intervals shown below.

<u>Material</u>	<u>Carbon to Nitrogen Ratio (C/N)</u>					
	<u>Composting Time (days)</u>					
	<u>5</u>	<u>10</u>	<u>20</u>	<u>30</u>	<u>40</u>	<u>50</u>
1 Leaves	50	54	52	-	53	51
1/2 Leaves - 1/2 Refuse*	-	48	51	39	43	35
1/4 Leaves - 3/4 Refuse	39	41	37	30	27	24
1/4 Leaves - 3/4 Refuse**	40	40	40	33	32	27

*Dry weight ratio.

**Leaves were ground.

Results of the C/N analyses indicate that in the absence of refuse, unground leaves would not decompose within the limits of the composting cycle normally used in this process. It appears however, that refuse will aid the decomposition of the unground leaves, especially when mixed in a ratio of 3 parts refuse to 1 part unground leaves (by dry weight). At this ratio, there appeared to be little difference in composting rate between the unground leaves and the ground leaves. Temperature measurements of each test windrow also confirmed the existence of these general trends.

The windrow containing only leaves was allowed to remain on the field for an additional 50 days. The C/N ratio at the end of the 100 days was 46, indicating that little decomposition had occurred, inasmuch as the original C/N was 50.

The windrows containing 50 percent (of total weight) or more leaves were difficult to turn in that the windrow turning machine frequently became clogged because of the larger windrow volume caused by the addition of leaves.

While the data are only preliminary, they do indicate that some leaves (at least in a ratio of 3 parts refuse to 1 part leaves by dry weight) collected by a municipality could be disposed of without being ground by composting them directly with municipal refuse. No detrimental effects to the routine composting cycle would be expected. The leaves did appear to enhance the appearance of the resulting compost.

Drying the Compost

A grain dryer was rented for the purpose of drying compost for use in the air classifier evaluation. While the installation and operation were somewhat inefficient, the dryer served its intended purpose (Figures 3 and 4).

Three test runs were completed using an average of 33 tons (wet weight) of composted refuse. The average moisture content



Figure 3. A grain dryer was used to dry unscreened and screened composted refuse.

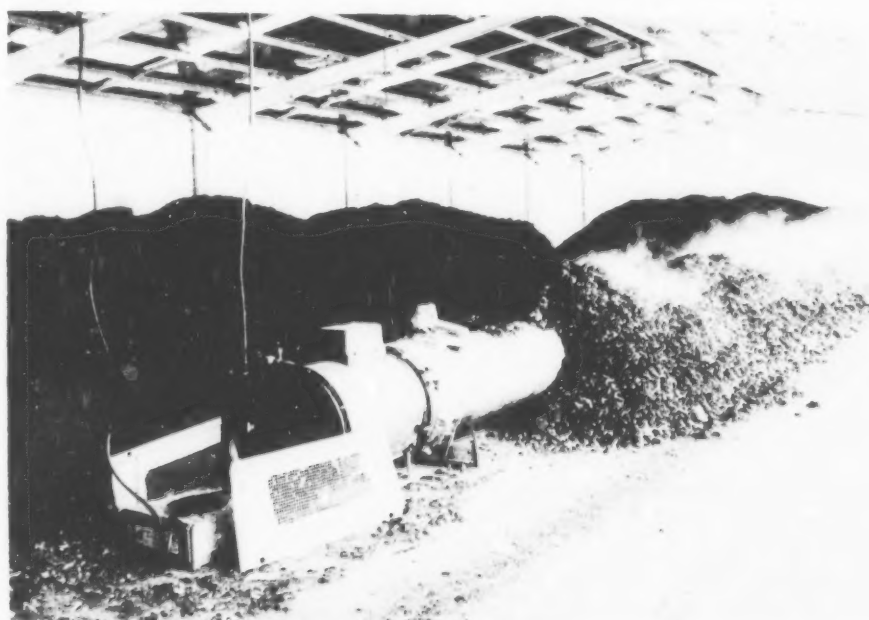


Figure 4. A grain dryer was used to dry unscreened composted refuse. Note the water vapor being forced from the material.

of the compost in the runs was 47 percent (wet weight). After two hours of drying, the moisture was reduced to an average of 38 percent (wet weight) at a cost of \$0.23 per ton initial material. After 3.5 hours of drying time, the moisture level was reduced to 16 percent (wet weight) at an average operating cost of \$0.29 per ton initial material.

This type of dryer, with properly designed ducts and layout, could provide an acceptable means for drying large quantities of compost for processing.

Screening Composted Refuse

Screening Process. The screening process as used to screen the composted refuse is depicted in Figure 5.

The scalping screen, fabricated of six 12 x 4 feet - 3/4 inch expanded metal sheets with 3/4 x 1-1/4 -inch diamond shape openings, was installed for the purpose of removing the larger pieces of plastic film, glass, metal, and similar materials prior to passage to the vibrating screen. It was felt that perhaps this screen would permit more efficient screening through the vibrating screen and negate the need for the previously installed rotary screen. However, while a slight improvement in the operation of the vibrating screen was noted, it did not permit removing the rotary screen because a large amount of acceptable composted refuse continued to be passed to the rotary screen for screening. Material

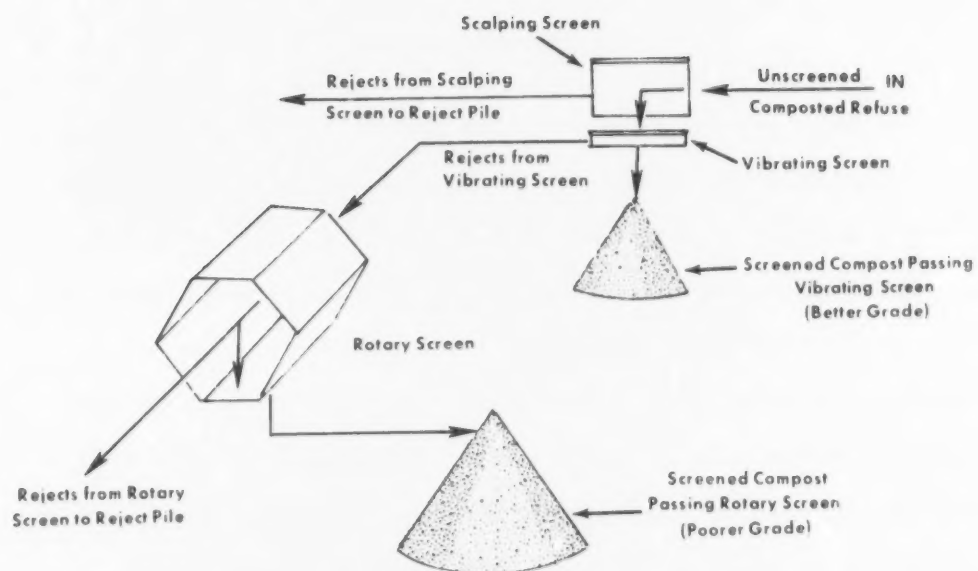


Figure 5. Screening process used to screen the composted refuse.

passing the scalping screen was fed to the vibrating screen. Material not passing the scalper was rejected.

The vibrating screen is an inclined screen with 7/16 inch hexagonal openings. In initial trials, wire mesh screens with openings of 1/4 and 1/2 inches were used. They proved to be unsuitable because the material clogged the screen. Material that passed through this screen was more thoroughly decomposed and was the most acceptable of the product in terms of both appearance and C/N ratio (Table 7 and Figure 6). Material not passing this screen was transferred to the rotary screen.

The rotary screen consisted of six 4- x 16-foot screens with 7/16 inch hexagonal shaped openings arranged in hexahedron shape. Material passing through this screen comprised the poorest grade of screened compost as it contained more of the noncomposted or partially composted cardboard and glass particles than did that which passed through the vibrating screen. Material not passing through it was rejected. However, while the material that passed through the rotary screen was of a rougher grade than that passed through the vibrating screen (Table 7 and Figure 7), it was acceptable for many uses, especially for land reclamation projects.

Analysis of samples taken prior to screening and after screening indicated that significant amounts of polychlorinated biphenyls in the composted refuse were being removed by screening.⁶ This is an indication that many plastic materials were being removed.

TABLE 7
CARBON TO NITROGEN RATIO OF COMPOST FROM
VIBRATING SCREEN AND ROTARY SCREEN

<u>Sampling</u>	<u>C/N of Compost</u>	
	<u>Vibrating Screen</u>	<u>Rotary Screen</u>
I*	28	30
	28	34
	30	35
	28	32
	30	45
	<u>20</u>	<u>23</u>
	Average	27
II**	22	25
	18	21
	19	21
	22	25
	27	30
	29	33
	<u>21</u>	<u>31</u>
	Average	23
Average of All Screened Compost = 28		

*Special test windrows - grinding study.
**Sampling of randomly selected windrows.



Figure 6. A better compost was obtained by screening through a vibrating screen. Note the difference in the appearance of this product and the material that was screened through the rotary screen (Figure 7).



Figure 7. The compost rejected by the vibrating screen was screened by the rotary screen. This was a poorer compost (Figure 6).

As discussed in Volume I, grinding of the screened compost was not a successful operation. Additional attempts made during this reporting period with the use of the Sedberry grinder, were again unsuccessful.

Compost Screening Rates. Records were maintained over different periods to determine the rate of screening the composted refuse.

In 109 total hours (actual running time), 868 tons of composted refuse were screened at a rate of 8 tons per hour on a wet weight basis. Thirty-seven percent (316 tons) of this material passed through the vibrating screen at approximately 2.9 tons per hour. Of the material rejected by the vibrating screen 251 tons, equivalent to 29% of the initial weight, passed through the rotary screen at a rate of 2.3 tons per hour. Therefore, the total production of screened compost was 567 tons (66 percent) at a rate of 5.2 tons per hour (wet weight basis). Based upon random sampling, screened compost averaged 46 percent moisture. Therefore, the dry weight processing rate for producing screened compost would be 2.8 tons per hour. This is the same average rate achieved during processing of the special test windrows for the grinding study. Rejects during this screening totalled 34 percent (301 tons) of the material fed to the screens. While the scalping screen aided the overall screening operation somewhat, it could be removed without undue effect upon the product or process.

The zig-zag air classifier* could be connected directly in line to process material produced by either the vibrating screen or the rotary screen. The classifier has the capacity to handle the production from either or both of the screens. However, since the material from the vibrating screen is superior in quality, it would not be desirable to process the product of both screens at one time unless the products are to be stockpiled for a period before use. This storage would act as an additional curing time for the rotary screened material.

Air Classification of Compost

The presence of glass and other dense particles small enough to pass the screens used in screening the composted refuse resulted in a compost product objectionable for some uses. Preliminary data obtained at Sanford Research Institute indicated that a zig-zag air classifier could remove such glass.⁷ Subsequently, a unit was procured for installation at the Johnson City composting project.

The unit was designed to process 16,000 pounds of compost per hour. It was constructed with a 10-stage, 8-inch by 45-inch SSI zig-zag air column, a 51-inch clockwise cyclone, a 10-inch rotary discharge valve equipped with motors and drive, and a 35-inch industrial fan with a 7-1/2 horsepower drive motor.

*Discussed in later section.

The contractor performed some preliminary operational test runs of the equipment on site. Results indicated that the unit offered the potential to effect a satisfactory separation of glass from the undried screened compost, and that it would also adequately separate plastic film from the ground refuse (Table 8).

To obtain operating data on this unit and establish optimum operating conditions, a statistically designed evaluation was planned. However, seasonal weather conditions and operating problems with the unit delayed this evaluation. Shortly after the preliminary operations began the drive shaft on the feed hopper broke within less than 20 hours of operation. At the time this happened, the unit was processing material screened through the rotary screen, probably the lightest job the classifier would be expected to handle.

On the basis of information obtained from the SRI contractor and preliminary testing at Johnson City, experiments were designed for the following:

1. To define the critical velocity levels for separating the various materials in ground solid waste (without screening).
2. To determine the classifier's capability for removing glass from the screened compost.
3. To determine the classifier's capability for removing plastics from the ground refuse prior to composting.
4. To determine the classifier's capability to remove glass from the ground refuse prior to composting.

TABLE 8
RESULTS OF INITIAL OPERATIONAL TESTING OF ZIG-ZAG

AIR CLASSIFIER

Material Tested	Pressure Drop Across Column (In H ₂ O)	Remarks
Raw refuse from rasper	6	Removed all glass except sand size
Raw refuse from rasper	0.3 to 0.5	Removed most plastic film
Composted refuse 42-days (field)	6	Removed most glass
Composted refuse 42-days (field)	0.5	Removed most plastic film
Wet screened composted refuse rotary screen	6	Wet compost formed mud balls around glass (Lost approximately 10% compost with glass)
Wet screened composted refuse rotary screen	0.5	Removed most plastic film
Wet screened composted refuse vibrating screen	6	Removed all glass except sand size (About 90% of feed removed as lights)

The delay in initiating the evaluation made it impossible to complete the investigations. Therefore, objective number 2 was selected as having the most importance, since fulfilling it would supply information relative to the original purpose for purchasing the classifier. Objective number 4 was modified and was fulfilled in its modified form.

Information available indicates the following:

1. For the purpose of removing objectionable glass particles from screened composted refuse, apparently no significant difference exists between the wet material (approximately 35 percent moisture - wet weight) and dry material (15 percent moisture). The best operating condition was with a pressure drop of between 4.6 and 6 inches of water. The 6-inch level resulted in a greater loss of compost in the heavy glass fraction, but produced a product free of objectionable glass particles. Although test conditions involved a feed rate of about 4 to 5 T/hour, indications were that with properly screened and dried compost the air classifier could process somewhat more and possibly even attain the designed rate of 8 T/hour.

2. The classifier as designed was not adequate for processing ground raw refuse or unscreened composted refuse. The difficulties were apparently the result of inadequate design for processing such materials (see number 4). The tests conducted with ground raw refuse and unscreened material did show that the classifier will remove most of the plastic film from these materials.

3. Operating difficulties encountered during testing involved an accumulation of the wet screened compost (light fraction) in the horizontal transfer duct between the zig-zag column outlet and the cyclone inlet. This could possibly be eliminated by designing the duct to have a steeper incline. Processing the dry compost created a dust problem, however, the dust could be controlled by appropriate dust collectors.

4. With respect to the ground refuse and unscreened material, the cyclone discharge valve was too small and often became clogged with the lighter material. Moreover, feeder blades, located in the feed hopper to the zig-zag column, were too small to freely process this rough material. Even though the feed rate was reduced to approximately 1 T/hour, clogging still occurred and resulted in damage to the blades. Larger feeder blades, spring loaded to "give" when metals, glass, and other similar objects tend to lodge between the blades and the wall, would help to solve this problem. It was found advisable to replace the neoprene seals on the feeder blades with thicker seals. The capability of creating a larger pressure drop across the column (and thus a greater air velocity) would be desirable for processing these rough materials. Wear data due to the pressure of such materials are not available. On the basis of limited observations, the processing of large quantities of screened compost containing glass particles would probably result in excessive

wear of the neoprene seals and the metal plates in the zig-zag column. Processing of raw ground refuse may result in more severe wear. Based upon the testing, the unit as installed and modified at Johnson City is capable of removing objectionable glass from screened composted refuse. Prescreening is recommended because tests with only coarse screening and with no screening did not produce an acceptable product. Recycling of the light fraction in these cases did not prove successful. The unit, as designed, is not recommended for processing raw refuse, unless the refuse is ground to a finer particle size than was produced at Johnson City.

Quality of Compost Produced at Johnson City

The physical appearance of the compost produced at Johnson City improved during the course of this reporting period. This improvement was primarily the result of improved screening operations. Some material processed through the air classifier was trucked to Horticultural Crops Research Center, North Carolina State University, Fletcher, North Carolina. The investigators were exceptionally pleased with the physical appearance and noted the absence of glass from the product.⁸

A number of analyses made during the last year of the project afforded an opportunity to obtain information relative to the quality of compost being produced. Compost produced at a Brikallare process

composting plant at Blaubeuran, West Germany, was analyzed by personnel of BSWM and compared with compost produced at Johnson City by the windrowing process.

Differences were noted in some of the parameters tested; however, neither compost appeared to be superior in any significant characteristic (Tables 9 and 10). Few data were available to permit a comparison of soil and plant responses to the respective composts. The data that were available, however, did not provide any reason to suspect that one would show a significant improvement over the other in this respect.

Results of tests reported in Volume I indicated that the average C/N of routine 42-day old composted refuse was approximately 34. The average C/N obtained for all samples of compost assayed during the present period was 28, with one set from the vibrating screen averaging as low as 23. The best C/N for any windrow was 18. A ratio of 20 or less is generally agreed to be optimum.

It would appear that the major objectionable feature of the compost produced at Johnson City during this reporting period was the quantity of glass remaining in the product. However, there are methods to remove the glass, the air classifier being one. A problem that was noted in the study was the lack of a standard for characterizing compost. Compost has been used to describe almost anything from unmilled raw refuse to completely decomposed animal wastes free of glass, plastics, and other

TABLE 9
CHEMICAL CHARACTERISTICS OF JOHNSON CITY
AND WEST GERMAN COMPOST

	Johnson City		German Compost
	Compost #1	Compost #2	
Carbon-total %	20.45	21.89	27.14
organic	19.39	20.82	24.44
inorganic*	1.06	1.07	2.71
Nitrogen (Kejeldahl) %	0.91	0.98	1.18
C/N ratio	22.47	22.37	23.00
Hydrogen %	2.59	2.72	1.95
Oxygen-total %	16.94	18.27	18.12
organic	12.71	14.00	7.27
inorganic*	4.23	4.27	10.71
P. %	0.31	0.34	0.37
C.O.D. (mg/gram)	414	420	339
Volatile (600 C) %	39.90	42.70	40.08
Ash (600 C) %	60.10	57.30	59.92
Volatile (950 C) %	41.53	44.53	49.07
Ash (950 C)%	58.47	55.47	50.93
BTU/lb	3576	2714	3848
pH _a (1 part sample + 2 parts water w/v)**	7.5	7.3	7.6
b (1 part sample + 50 parts water w/v)**	8.5	7.9	8.4

*From carbonate.

**Proportions proposed by Carnes and Lossin in their study of the buffer systems in compost.

TABLE 10
ULTIMATE ANALYSIS OF JOHNSON CITY AND GERMAN COMPOSTS

	Johnson City Compost		German	
	ug/gram or ppm	%	ug/gram or ppm	%
K	1692	0.17	1974	0.20
Na	2786	0.27	1136	0.12
Ca	19811	1.98	63733	6.37
Mg	4376	0.44	3979	0.39
Fe	2407	0.24	2467	0.25
Al	7005	0.71	7669	0.77
Cu	370	0.04	257	0.03
Mn	418	0.04	520	0.05
Ni	24	0.002	20	0.002
B	321	0.03	277	0.03
Zn	776	0.08	590	0.06
Hg	0.18	0.00002	N.D.	----
Pb	4.83	0.0005	6.33	0.0007

objectionable matter. Therefore, difficulty arises in trying to compare data between projects because of this lack of a suitable standard. As an example, the "compost" applied to the "Cane Patch" strip mine demonstration in 1968* was unscreened material and contained large quantities of glass, plastic, can opening tabs, and many similar items. The "compost" presently being applied in the demonstrations is relatively free of such items after screening. Yet, both products are designated as compost. Compost produced from food wastes, animal wastes, leaves, and similar organic materials would be expected to be of a better quality than compost produced from mixed municipal refuse, yet both products are called compost. The same situation exists for material that has been stored and aged for years as compared to material that has only composted for a few weeks. There exists a need to establish standards for compost. Standards should, as an example, include:

Moisture, when package	%
Organic matter	%
Inert material	%
Maximum glass	%
Nitrogen	%
Phosphorous	%
Principal Constituents	%

*See section "Compost Utilization Research and Demonstrations."

Ground Refuse	%
Sewage Sludge	%
Animal Manure	%

Particle Size, etc.

These are offered as examples only. As more is learned concerning potential effects on soils, plants, etc. from heavy metals and other trace materials which might be present in the compost, provisions would be needed to measure and report such things, as they may determine the final recommended disposition of the compost.

SUMMARY OF MEDICAL SURVEILLANCE

The compost demonstration project involved work with potential occupational exposures that had not been previously encountered. Responsibility for health surveillance of employees at the composting plant was assigned to the Knoxville Medical Office of the TVA.

Before the plant was put into operation on June 20, 1967, all TVA operating employees at the project had received pre-employment physical examinations. They were also tested for tuberculosis and histoplasmosis and immunized against smallpox and typhoid. Public Health Service employees at the project were also provided these tests and immunizations. Regularly scheduled medical services included typhoid, tetanus toxoid, smallpox, and poliomyelitis immunizations which were kept current throughout each employee's entire period of employment. Influenza and Rocky Mountain spotted fever vaccines were administered to employees who wanted them.

Close surveillance over health status and health needs of employees was maintained. The Chief, Eastern Area Medical Service and the Supervising Nurse of the Eastern Area made more frequent visits to the project than are ordinarily required for most TVA field projects. They also were in frequent communication with supervisors in both TVA and PHS. Annual chest X-rays were performed either in the Knoxville Medical Office or through arrangements with private medical facilities in Johnson City. Periodic health examinations were performed on the Mobile Health Clinic, with followup by the Chief, Eastern Area Medical Service, or in the Knoxville Medical Office.

The Nurse in the Mobile Health Station assigned to the Eastern Area of the Division of Power Construction was located in the Johnson City area for over a year while the composting plant was in operation. She visited the plant to administer and interpret tests and immunizations and provided other services such as treatment of injuries and illness. First-aid kits and supplies were maintained at the plant site for treatment of minor injuries.

Unexpected positive reactions to annual tuberculin skin tests were discovered in 7 of 13 employees at the compost plant in October 1968. Follow-up chest X-rays were performed on all employees with interpretation by a radiologist. No significant abnormalities

were disclosed. After consultation with the National Communitive Disease Center representatives, it was tentatively concluded that contact with human tuberculosis bacillus had occurred but was unrelated to the compost material. Each worker who reacted positively was kept under surveillance and received additional tests periodically.

In November of 1969, the 16 employees at the project (TVA and PHS) were given onsite physical examinations which included chest X-ray, electrocardiogram, tonometry, urinalysis, and complete blood analyses by the SMA-12 and SMA-7 in the Central Medical Laboratory, Chattanooga. No significant abnormalities were found. A TVA physician reviewed the results of the examinations with each employee.

With the discontinuance of plant operation on June 30, 1971, medical services for the project ended.

COMPOST UTILIZATION RESEARCH AND DEMONSTRATIONS

Evaluating a material such as compost, which has very little inorganic fertilizer value, is extremely difficult since any response brought about by its use on crops would be expected to accrue over a number of years. Physical properties of the soil do not change rapidly excepting as a result of extreme stress. The objective of the compost research projects and demonstrations was to study crop responses and changes in soil characteristics from use of the compost under varying conditions, and thereby provide a better basis on which to evaluate the material.

The research projects were statistically designed and controlled experiments established to obtain research data on crop and soil responses to composted municipal refuse. The demonstrations were established in cooperation with farmers and other users to obtain data about the use of compost under actual field conditions. The conditions under which the demonstrations were carried out were not as completely controlled as for the research projects, but they do provide data with respect to user reaction and evaluation of the compost.

Compost Utilization Demonstrations

The primary objective of the compost demonstrations was to investigate the potential uses of compost and its effects on crop production in each use under actual field conditions. Also important was introducing the product to potential users and observing their reactions with respect to specific conditions of use. The demonstrations have helped determine some of the benefits and problems associated with the use of compost as a soil conditioner.

Demonstrations were established on field crops, horticultural crops, home gardens, lawn establishments, road bank stabilization, and for the reclamation of spoiled lands. During two years, 172 demonstrations--using approximately 4,775 tons of compost--were established by the TVA Agriculturist.

The following evaluation of the demonstrations is based primarily on those projects which were conducted over a two-year period. Special-interest demonstrations are also included.

Reclaiming a Fly Ash Pond. Fly ash ponds result in conjunction with TVA steam power generating plants. Ponds receive the ash created by the burning of coal. Little success has been achieved in reclaiming these areas by conventional means. This project was established at the John Sevier Steam Plant in Rogersville, Tennessee. Preliminary results (Figures 8 and 9) appear excellent but full evaluation will require observation over the next two to three years.

Compost is Successfully Used to Grow Burley Tobacco. Burley tobacco is the leading cash crop in upper east Tennessee. There are over 2,000 acres of tobacco allotted to Washington County--an average of 0.5 acres per farm. The average yield in 1968 was 2,414 pounds per acre (lbs/A); in 1969, 2,448 lbs/A; and 1970, 2,649 lbs/A. The average market price for burley tobacco is about \$70 per hundred-weight (\$70/cwt.). The gross annual farm income from tobacco sales in Washington County is greater than \$3.5 million.

Tobacco is often grown in the same soil each year until yields begin to decrease or disease forces the farmer into a rotation with other crops. When this happens, less fertile soil is used to produce tobacco. Maintaining good soil conditions is therefore essential. The farmer may apply barnyard manure



Figure 8. A fly ash pond at the John Sevier Steam Plant, Rogersville, Tennessee was barren of plant life prior to reclaiming with compost, fertilizer, and seed in September 1970.

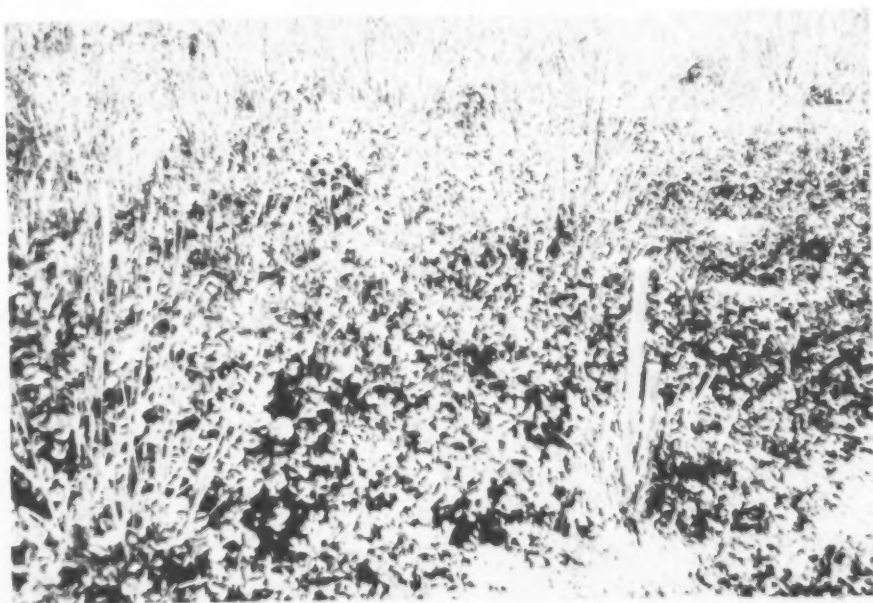


Figure 9. The reclaimed fly ash pond shows good plant growth in July, 1971.

and plow under green cover crops to help replenish the soil organic matter that is diminished by the large applications of inorganic fertilizers needed for burley tobacco. Twenty-five demonstrations were initiated to observe the effects of compost as a potential organic supplement for growing burley tobacco.

Using application rates of 12 to 60 tons per acre (T/A), the demonstrations show compost to have positive physical effects on many soils used for growing burley tobacco in east Tennessee and western North Carolina. None of the demonstrations produced adverse effects on tobacco yields. On several projects, yields were increased when compared to plots not receiving a treatment of compost. The most favorable response from the use of compost has been on soils that have been intensely cropped without benefits from applications of barnyard manures or green cover crops.

Compost compares favorably with barnyard manures as an organic supplement, and the presence of certain trace elements in compost can be beneficial when applied in proper amounts to deficient soils.

Results from demonstrations thus far have shown that compost has residual value on subsequent crops of tobacco. If "uncured" or "green" compost is applied in large quantities immediately prior to planting tobacco, certain plant nutrients are immobilized

while the compost is undergoing further microbial decomposition. This condition can be corrected by adding inorganic fertilizers, reducing the application rates, or applying the compost well in advance of the tobacco crop. Longer composting times and/or curing times will also correct this situation.

The addition of compost to tobacco soils can be beneficial in maintaining or correcting adverse pH conditions. Since compost has some liming effects, the addition of compost to the normal inorganic fertilizer program can be expected to have a positive synergistic effect on acid soils.

A preliminary survey of farmers in the area indicates a positive demand for compost as an organic amendment for growing burley tobacco in east Tennessee and western North Carolina. These results are based on one to three consecutive years of observation. The effects of annual applications of large quantities of compost over long periods of time are not known. Present results, however, do indicate that with proper management, compost can be used effectively on tobacco soils.

Compost Proves Beneficial in Growing Corn. Although corn is usually considered a low-value cash crop, it is important in the area. A large percentage of the corn produced is fed to dairy or beef cattle as silage. Farms are small and intense cropping practices are followed. Dairy and beef cattle farmers have little

need for outside organic supplements since their own operations supply large quantities. However, many part-time farmers with no source of organic manures still grow corn for human consumption either at home or in local markets. This situation creates a possible outlet for compost.

The results from demonstrations on corn thus far indicate substantial benefits from compost. Figures 10, 11, and 12 serve to illustrate these results. The addition of compost to soils used for growing corn can increase yields, improve soil moisture relationship, improve bulk density, and increase organic matter. The increased corn yields, as in some other crops, is offset by the costs involved in hauling and spreading the compost. The benefits from using compost on corn are improved when the corn is harvested for silage. This is attributed to the fact that for silage the entire stalk of corn is harvested while for grain the entire stalk remains intact and can be plowed back into the soil as an organic supplement.

The addition of compost to infertile, non-productive soils can improve soil conditions and increase the productive capacity of these soils. However, the long-range effects, from continuous application of large quantities of compost, on soil-plant-animal relationships have not been defined.

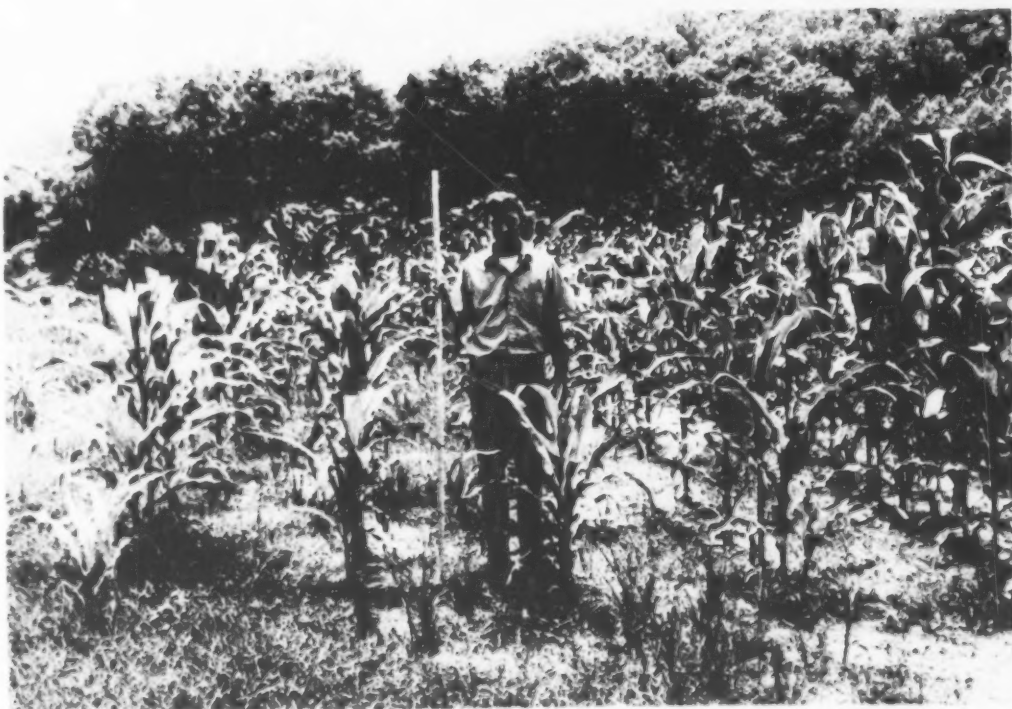


Figure 10. The control plot (nitrogen and compost not used) has fewer and smaller corn stalks than the composted plots shown in figures 11 and 12, (Photographed in July 1971).



Figure 11. The corn grain research plot receiving a complete fertilizer treatment but no compost shows fewer and smaller corn stalks in July 1971 than the corn treated with 100 tons per acre of compost only (Figure 12)



Figure 12. The corn plot receiving 100 tons per acre of compost but no nitrogen fertilizer shows larger corn and more corn stalks than plots receiving only fertilizer (Figure 11) and no fertilizer (Figure 10).

Compost as an Organic Supplement for Horticultural Crops.

The production of high-value horticultural cash crops in upper east Tennessee and western North Carolina is being recommended as a means of supplementing farm income. The restrictions on tobacco allotments are largely responsible for these recommendations. The acreage of highly productive soil is small and is not entirely the result of topography. Another factor is that inadequate farm practices have resulted in excessive erosion.

The need for maintaining the productive capacity of soils is extremely important. Increased total population in the area combined with a decrease in farm population and more competitive marketing have made it necessary to increase production simultaneously with a decrease in acreage allotments for tobacco. To meet these production demands, the farmer has relied on inorganic fertilizers, which in turn have increased the need for maintaining or improving the soil organic matter--normally provided in the form of barnyard manure and green cover crops. Compost may be an adequate substitute and provide valuable trace minerals as well.

For certain horticultural crops, such as tomatoes, the yield may be increased by the practice of mulching for weed control and conservation of moisture. In this area either straw or plastic sheeting is used. Five demonstrations using compost on tomatoes were begun in 1970. In four of these, compost was applied as

a mulch; and in the fifth, it was plowed under prior to planting. No observable beneficial results were obtained from plowing in the compost, whereas using compost as a mulch resulted in a notable increase in yield. Good weed control, which is a requirement for a good mulch, also was obtained. More detailed demonstrations will be established in 1971 to determine the effect of compost on soil and plants.

Demonstrations on horticultural crops indicate that compost has potential as an organic supplement. The response from compost users has been favorable. The interest generated on behalf of many home gardeners has become widespread throughout the area. Compost relatively free from glass and other foreign matter could be marketed locally based on response from those using or observing results from compost in previous cooperative demonstrations.

No adverse effects from the use of compost have been observed thus far; however, supplemental research and demonstrations are necessary to establish guidelines for the use of compost especially when fortified with municipal sewage sludges.

Compost as a Mulch for Flowers, Trees, and Shrubs. Twenty demonstrations were initiated in which compost was used as a mulch for shrubs, flowers, and trees. There was no report of compost adversely affecting growth in any of the demonstrations even when applied up to six inches deep. Compost, used as a

mulch and worked into the soil, gave excellent results when applied to flower beds, particularly roses. Some adverse growth patterns were experienced when acid-loving shrubs were planted directly into a compost-soil medium. The possibility of adjusting the pH of the compost to increase the utility of the product is being studied.

Use of Compost for Establishing Grass Sod. Fifteen demonstrations were established which involved the starting or maintenance of grass sod on lawns, pastures, and golf courses. Compost apparently was of little value when applied as a topdressing for lawn or pasture maintenance. Although there was a difference between areas receiving compost and those receiving none, it is doubtful that the economic benefit would be worth the costs of hauling and spreading. This may not be the case in the maintenance of golf courses where compost has proven to be valuable supplement in maintaining tees and fairways. The golf professional at Johnson City Municipal Golf Course says that compost has been a valuable asset in his golf course operations. He places a value of \$10/T on the compost. Other than on golf courses, compost proved to be the most beneficial in grass establishment when disced into the soil rather than applied as a topdressing.

In similar demonstrations, compost definitely proved beneficial in aiding soil stabilization and grass establishment on areas where

efforts to obtain a sod cover had been less than satisfactory. In many of these instances, compost was disced into the soil. Figures 13, 14, 15, and 16 provide examples of the demonstrations and depict the results obtained.

Use of Compost in Reclaiming Strip-Mine Lands. There are about 800,000 acres of defaced strip mine land in the United States which need to be reclaimed or stabilized to reduce erosion and stream pollution. The use of chemical fertilizers and lime for reclaiming these areas may provide satisfactory initial results. However, due to recurring acidic conditions and lack of organic matter, such results are often short-lived. Preliminary research indicates that the most adverse effects from erosion occur during the first six months after strip mining. Therefore, this is the critical time for reclaiming operations since the most severe erosion occurs during this period, thereby removing most of the organic matter which might be present. With little organic matter, six months is not sufficient time for plants to develop, even with fertilizer applications. Thus, erosion continues. Even if immediate seeding and fertilization are accomplished, the absence of soil and organic matter for a good seedbed often prevents the plant root development needed to check erosion. Even repeated seeding and fertilizer treatments do not assure satisfactory results.

The potential value of compost in reclaiming these strip mine spoils has been apparent in demonstrations conducted to



Figure 13. A roadbank at the Boone Dam TVA Reservation was stabilized with compost in the summer of 1969. The bank shows thick grass cover in July 1971

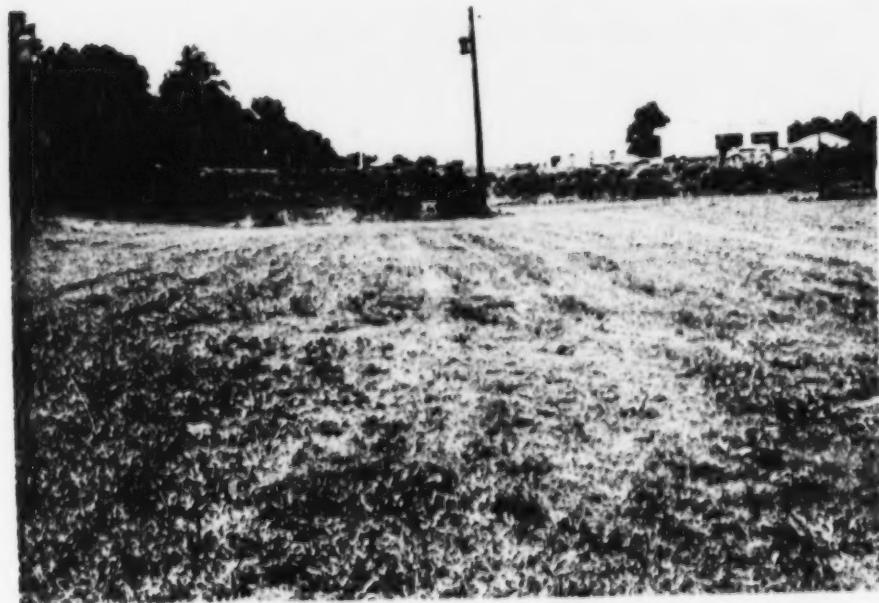


Figure 14. A play area at the Municipal Park, Jonesboro, Tennessee was stabilized with compost in 1968. For eight years erosion formed a ditch requiring fill soil and seeding each year. This photograph was taken in July, 1971.

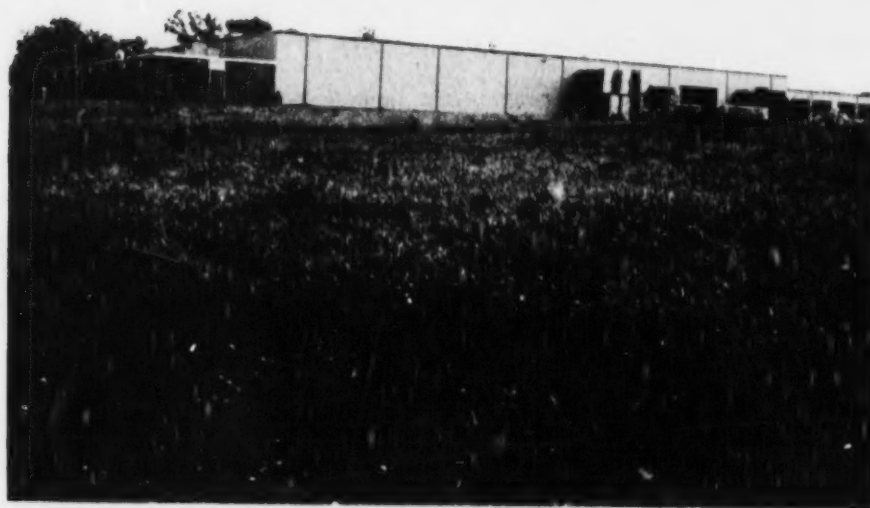


Figure 15. Compost was used in the spring of 1968 to help establish the ground cover shown in July 1971.



Figure 16. In July 1971 land at the Tri-Cities Airport is covered with a good growth of grass. The area was treated with 30 tons per acre of compost in 1970 after earlier conventional seeding methods had failed.

date (Figures 17 and 18). Superior results have been achieved where compost was applied as a mulch to supplement a fertilizer and seeding program. The long term effects of using compost in strip mine reclamation programs would appear to be desirable. Compost rates up to 180 T/A have been used successfully in demonstrations. As a supplement to the compost utilization demonstration on strip mines, a research project designed to provide information about the optimum rates of application of compost needed to reclaim the strip mines was initiated in October 1970. Data will have to be collected over several years to obtain meaningful results. Preliminary results, however, are encouraging (Figures 19 and 20) and indicate favorable responses to amounts of compost lesser than those applied in the 1968 demonstration.

Summary of Compost Utilization Demonstrations. After the first year, most cooperators felt that the compost was beneficial. They stated, however, that removal of the glass and plastic would increase the compost's utility. Less than five percent thought that compost was detrimental to crop growth. Improved water-holding capacity, improved soil tilth, and increased crop responses to inorganic fertilizers were favorable benefits attributed to the compost by the users.

During the first year of the demonstrations, much of the responsibility of getting the material into the soil was left to



Figure 17. In 1968, this area of the "Cane Patch" strip mine which had remained barren for approximately 13 years received fertilizer and seeding treatments. Two areas also received 72 tons/acre and 184 tons/acre of unscreened compost. Note the severe soil conditions and erosion on the control area in the foreground. The edge of the compost treated area is in the background. See Figure 18. (Photographed July 1971).

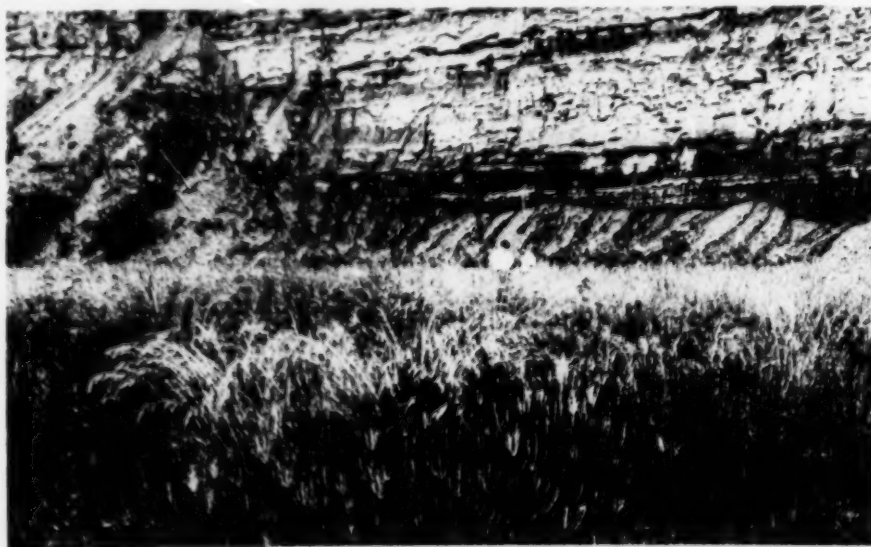


Figure 18. The "Cane Patch" strip mine compost demonstration shows the lush growth of grass, natural vegetation, and pine trees remaining after over 3 years since planting on compost treated areas. See Figure 17. (Photographed July 1971.)



Figure 19. This photograph of the experimental strip mine reclamation project shows the density of grass cover in July 1971 on plots receiving the smallest rates (14 dry tons/acre) of compost. The project was begun in the fall of 1970.



Figure 20. This photograph of the experimental strip mine reclamation project shows the grass growth in July 1971 on the plots receiving the largest amounts (26 dry tons/acre) of compost.

the individual user. The majority of the material was hauled in dump trucks by TVA and left in stockpiles at the test sites. Since in most cases there were no mechanical means of spreading the compost on the fields, the individual user was asked to spread the material.

The willingness of most cooperators to try a new product was most encouraging, especially since the physical appearance of the compost at that time was unacceptable because the screening process was not established. Most of the individuals made an effort to follow instructions concerning its use.

During the second year of demonstrations, the procurement of a truck with compost spreading equipment (Figure 21) eliminated the need for the user to spread the material. This resulted in more reliable application data. Also, the physical appearance of the compost was greatly improved as a result of better screening. This increased its potential uses and also improved public reaction with respect to the demonstrations. However, compost for the "carriage" trade would have required the removal of more glass.

Results from two years of compost demonstrations were more favorable than those from one year's demonstration. Most cooperators felt that compost could be beneficial to crops but the cost of distribution would be expensive. None thought compost was detrimental to crop growth. Benefits listed by cooperators were improved



Figure 21. A truck with a spreading attachment was used to apply compost on compost demonstration areas.

moisture-holding capacity, improved tilth, easier tillage, and increased response to inorganic fertilizers. The value users placed on the compost averaged \$5.80 per ton. In addition, composting may provide an ecologically desirable means of disposing of organic solid wastes.

The compost used in the tests improved the pH of the soil, increased the soil's moisture-holding capacity, and improved the soil's bulk density. Significant increases in the yields of grain sorghum, corn, and bermudagrass were obtained. In corn experiments, a value of \$1.65 to \$5.80 per ton was estimated for the compost on the basis of yield only. The value for the compost when used with grain sorghum was estimated to be from \$1.10 to \$2.20 per ton.

The most favorable responses to compost applications, based on two years of demonstrations, occurred with: (1) high-value cash crops, (2) soil stabilization and erosion control projects, and (3) home and garden uses. However, the effects of continuous and intermittent use of large quantities of compost on soils and plants are yet to be determined. Since compost contains many elements, the possibility of an accumulation of an element or elements in excessive amounts is possible--especially where large amounts of compost are applied annually.

Compost Utilization Research Projects

Experiments were designed to measure the response of indicator crops to compost. Tests using forage sorghum, common bermudagrass,

and corn were conducted during the 1969-71 seasons.^{4,9} These crops were selected because they are good indicator crops in research and are also important regional crops.

The forage sorghum and bermudagrass experiments were conducted by the Soils and Fertilizer Research Branch, Division of Agricultural Development, TVA, at the National Fertilizer Development Center at Muscle Shoals, Alabama. The corn grain research project was conducted at the Johnson City location by the Test and Demonstration Branch, Division of Agricultural Development, TVA.

Use of Compost for Sorghum Production. This experiment evaluated the effects of municipal compost and nitrogen applications on sorghum yields and soil characteristics. Prior to the 1969 and 1970 growing seasons, municipal compost from Johnson City, Tennessee, was applied in fall, spring, or combination applications at rates totaling from 0 to 146 tons per acre (T/A) for the 2 years on plots 12 by 30 feet each. Fall applied compost was plowed under shortly after application, while spring applications were incorporated into the soil by disking. Compost rates were compared with those involving 80 and 160 pounds of nitrogen per acre (lb/A), with three treatments supplying both nitrogen and compost, and a check treatment with no nitrogen or compost. Application methods and nitrogen treatments were the same in both years. Chemical analyses of the compost at the time of application were as follows:

	-----Element, (% dry weight)-----								
Application Time	N	P	K	C	Ca	Na	Mg	S	Zn
Fall 1968	1.2	0.24	0.80	34.2	3.6	0.49	0.49	0.4	0.13
Spring 1969	1.3	0.40	0.96	26.8	6.4	0.82	0.87	0.4	0.15
Fall 1960 and Spring 1970	1.3	0.26	0.97	27.3	4.6	0.67	0.60	0.5	0.15

Prior to planting, phosphorous and potassium were applied at rates adequate for maximum plant growth. Crops were harvested twice, at the early dough stage and a ratoon crop 2 to 3 months later.

Yields of forage sorghum in 1969 and 1970 (Table 11) increased in a curvilinear manner with increases in compost rates. Nitrogen plus compost resulted in greater yields than compost alone or nitrogen alone. Yields were lower in 1970 than in 1969 because of later planting and a less favorable mid-summer rainfall pattern. At the lower rates at which these comparisons were made, it made no difference whether compost was applied in the fall or spring or in split applications.

In 1969, 41 tons of compost was required to produce as much sorghum as 80 lb/A of nitrogen, while no amount of compost produced as much forage as 160 lb/A of nitrogen. In 1970, 16 T/A of compost produced yields equivalent to 160 lb/A of nitrogen, a

TABLE 11

FORAGE SORGHUM YIELD AND N UPTAKE AT MUSCLE SHOALS, AS AFFECTED BY COMPOST AND N RATES

Total compost applied T/A	Annual N rate lb/A	Total yield of forage sorghum, T/A			Total N uptake, lb/A*		
		1969	1970	1971	1969	1970	1971
		Avg.			Avg.		
0	0	5.4g	2.8h	4.2g	80g	41i	38g
0	80	6.9de	4.6e	4.8f	144d	90e	59f
10	0	5.8fg	3.3g	5.2de	85g	56h	61ef
0	160	8.2b	5.2d	4.7f	209ab	137b	60f
20	0	6.3e	3.7g	5.6bcd	102f	58gh	77c
16	0	5.9fg	3.6g	5.8bc	88fg	63g	75cd
18	0	6.2f	4.1f	5.6bcd	92fg	63fgh	68de
20	80	7.9bc	5.5bc	5.5bcd	169c	105d	74cd
20	160	8.9a	5.7b	5.4cd	200b	130c	65ef
37	0	6.2f	4.6e	5.8bc	101f	82f	81c
73	0	6.9de	5.2cd	6.1b	115e	91e	104b
146	0	7.5cd	6.3a	6.7a	141d	142b	135a
73	160	9.4a	6.5a	6.1b	217a	171a	105b

*Values having the same letter in each column are not significantly different at the 5% level.

result influenced to some extent by the residual effect from the 1969 compost application.

Residual yields taken in 1971 showed much the same response to compost as 1969 and 1970 yields; there was little residual effect from the nitrogen treatments.

The effects of compost and nitrogen on total nitrogen uptake were similar to those on yield except that nitrogen uptake was more linear with amounts of applied compost. As was true for yield, large tonnages of compost were required to equal the effect of even the 80 lb/A nitrogen application.

The relative effects of nitrogen and compost on total yield and nitrogen uptake over the 3-year period are shown graphically in Figure 22. The 20 T/A application of compost resulted in an average annual yield increase of 1 T/A or 3 tons over the 3-year period. This would have had a value of approximately \$75 or about \$1.65 per ton of compost applied. At rates above 20 T/A the yield increases had a value of about \$0.45 per ton of compost applied. Equating yield increases from compost with the cost of fertilizer nitrogen needed to give equivalent increases provides an even less favorable economic comparison, since 2 pounds of nitrogen produced almost as much yield increase as 1 ton of compost.

Table 12 shows the effect of compost and nitrogen on the concentration of elements in the whole sorghum plant. Nitrogen concentrations were increased somewhat by increasing compost

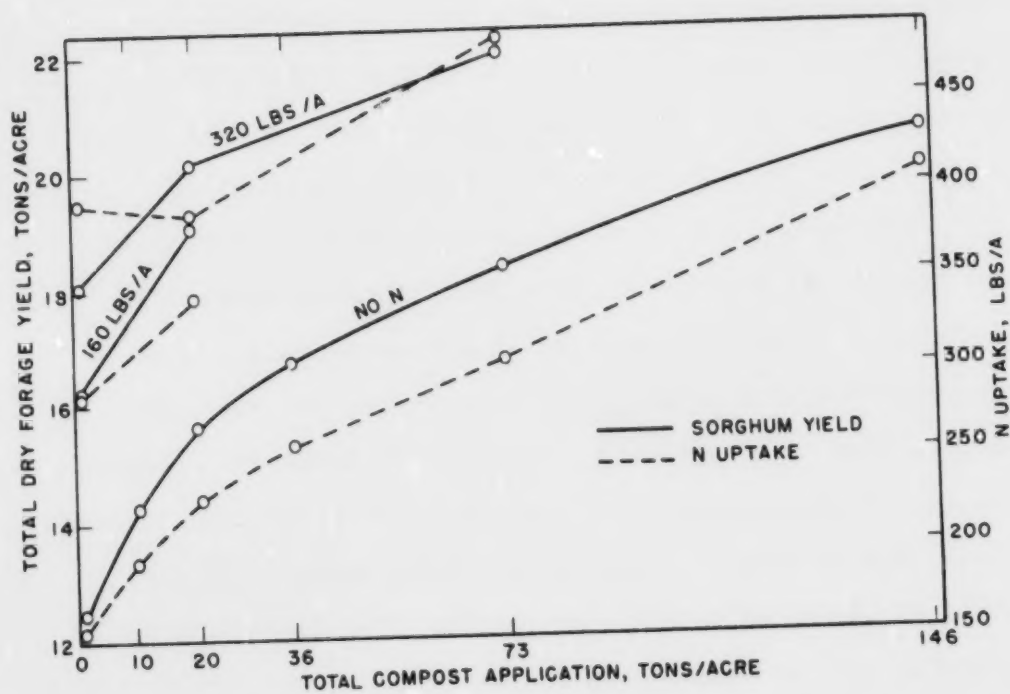


Figure 22. Three-year total Sorghum yield and nitrogen uptake as affected by compost and nitrogen rates of application.

TABLE 12
EFFECT OF COMPOST AND N ON NUTRIENT CONCENTRATION IN FORAGE SORGHUM, MUSCLE SHOALS

2-year total compost application, T/A	Annual N rate lb/A	Elemental concentration, first harvest 1970							
		N, %	P, %	K, %	Ca, %	Mg, %	Na, ppm	Zn, ppm	Cu, ppm
0	0	0.63	0.22	1.70	0.21	0.08	46	32	4.0
0	160	1.23	0.18	1.25	0.28	0.12	89	36	5.7
20	0	0.76	0.20	0.67	0.19	0.09	39	34	4.4
20	160	1.05	0.17	1.47	0.24	0.11	89	47	5.3
37	0	0.76	0.25	1.78	0.19	0.09	38	41	4.4
73	0	0.75	0.22	1.99	0.20	0.08	64	50	5.1
146	0	0.98	0.24	0.06	0.21	0.09	54	57	5.6
73	160	1.19	0.20	2.17	0.23	0.11	72	61	6.4

rates but less than with added fertilizer nitrogen. Phosphorus, Ca, and Mg concentrations changed little with increasing compost rates. Soil tests prior to initiating the experiment showed that these nutrients were present in the soil in adequate to luxury amounts.

Potassium levels were generally higher with increasing compost rates and lower with applied nitrogen. Other workers have reported refuse and sewage sludge to be low in potassium. However, when 50 or more tons per acre are applied, even very low concentrations of a nutrient result in large actual applications. Sodium concentration was of interest, since the newsprint component of refuse is high in Na. Compost application had relatively little effect on Na concentration except at very high compost rates, but nitrogen application increased it markedly, especially with no compost or at low rates, for an unknown reason. Zinc and Cu concentrations were increased by both compost and nitrogen. The rather large increase in Zn concentration in plant tissue as well as in the soil points up the need for careful chemical evaluation of sludges and composts before large tonnages are applied to soil to avoid heavy metal toxicity problems.

Several physical and chemical soil evaluations made after sorghum harvest in 1970 are summarized in Table 13. Bulk density and compression strength measured with a penetrometer were both

TABLE 13

EFFECT OF COMPOST AND N ON PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL AT MUSCLE SHOALS

2-year total compost application T/A	Annual N rate lb/A	Moisture holding capacity at 1/3 bar		Soil Moisture %	Bulk density*	Unconfined compression strength lb/sq in*	Organic matter %	pH	Extractable nutrients lb/A			
		%	z						K	Ca	Mg	Zn
0	0	11.1		12.4	1.37a	40a	1.58	.5	172	1471	161	6
0	160	--		11.0	1.37a	32b	1.47	5.1	138	1310	139	5
20	0	--		12.5	1.32ab	40a	1.81	6.2	175	2083	177	26
20	160	--		11.6	1.30bc	36ab	1.99	6.0	130	2034	172	31
37	0	--		12.9	1.27cd	36ab	1.96	6.2	205	2323	183	34
73	0	13.0		13.3	1.22e	33b	2.66	6.6	247	2981	199	81
146	0	15.3		14.8	1.12f	21d	4.22	6.8	295	3489	208	436
73	160	--		13.5	1.25de	26c	2.58	6.4	191	2831	168	77

*Values having the same letter in each column are not significantly different at the 5% level.

decreased significantly by heavy compost applications, while soil moisture content and moisture-holding capacity were increased. This improvement could be observed during every period of moisture stress, as less leaf curling occurred on all plots receiving 16 or more T/A annually.

Compost applied for the 1969 crop was quite coarse and the spring applications disked in at rates of 25 or 50 T/A prevented the preparation of a firm seedbed and caused a reduction in stand. No unfavorable physical effects were noted from finely ground compost applied for the 1970 crop.

Compost applications increased soil organic matter content from 1.6% with no compost to 4.2% at the highest compost rate. The effects of lower compost rates were intermediate. Levels of K, Ca, Mg, and Zn and pH were all increased. The increase in Zn level creates the potential for an unfavorable crop response. However, since compost resulted in pH values above 6.0 along with the higher Zn levels, no adverse effects of Zn were observed in this experiment.

Evaluation of Compost on Common Bermudagrass.⁹ Compost was topdressed on common bermudagrass sod in November 1968 at rates of 0, 4, 8, and 12 T/A. In the winter of 1969-70, compost was applied to the same plots at triple the 1968 rate. Nitrogen rates of 0 and 160 lb/A were superimposed on plots at each compost rate. One-half of the nitrogen was applied in April and the other half after the second harvest. The grass was cut four times.

Common bermudagrass yields (Table 14) show that bermudagrass sod can accept heavy applications of surface-applied compost and show a slight yield response. Without added nitrogen the high compost rate produced significantly more forage than no compost in 1969, while all compost rates were better than no compost in 1970. Where nitrogen was applied, compost did not increase yields significantly in 1969, but the two highest rates were better than no compost in 1970. As with sorghum, yield increases from compost were insufficient to pay the cost of composting, transportation, and application.

It seems that the most critical consideration for compost being used on forage land is the possible presence of glass, metal, or other foreign material in particles big enough to be ingested by grazing animals or picked up in harvested hay.

Corn Grain Research Project at Johnson City. This project was designed to evaluate the response of corn yields and soil characteristics to the addition of compost^{2,*}

Application rates for fall or spring-applied compost ranged from 0 to 200 T/A. The objective was to determine the soil and crop improvement resulting from various rates of compost and the maximum amounts of compost that can be applied without adverse affects. Fall applications of 4, 8, 50, 100, and 200 T/A were plowed under. Spring applications of compost were disked into

*See Figures 10, 11, and 12 for an indication of the plant growth response to the compost.

TABLE 14
COMMON BERMUDAGRASS YIELD, AS AFFECTED
BY COMPOST AND N, MUSCLE SHOALS

Compost rate, T/A		N rate, lb/A	Dry forage yield, T/A*		
1969	1970		1969	1970	Avg.
0	0	0	2.9c	1.2d	2.0d
0	0	160	5.1a	2.5b	3.8b
4	12	0	3.3bc	.18c	2.5c
4	12	160	5.0a	2.9ab	3.9b
8	24	0	3.4bc	2.8c	2.6c
8	24	160	5.6a	3.2a	4.4a
12	36	0	3.5b	2.1c	2.8c
12	36	160	5.3a	6.0a	4.1ab

*Values having the same letter in each column are not significantly different at the 5% level.

the soil. Nitrogen application rates of 80 and 160 lb/A were compared alone and with 8 T/A of spring-applied compost. Plot size was 12 by 30 feet with all treatments replicated 4 times. The area was fertilized with phosphorus and potassium at rates adequate for maximum plant growth.

After planting the soil was sprayed with 2-1/2 lb/A of Atrazine for weed control. The 1970 corn was planted late because early adverse weather conditions in 1969 accounted for some reduction in plant population. During the first year (1969), there was reduced germination in plots receiving 50, 100, and 200 T/A. During the second year (1970), no significant reduction in germination was observed, although some difficulty in preparing a firm seedbed was again noted in the 50, 100, and 200 T/A compost treatments.

It was also noted that throughout the research field the 50, 100, and 200 T/A treatments resulted in an increase in the elevation of the soil as compared to the other treatments. A nutrient deficiency was observed early in the 1969 growing season but was not evident in the 1970 crops, except in the control plot where nitrogen deficiency symptoms were noted. By observation, the 8 T/A compost + 160 lb/A nitrogen, and the 50, 100, and 200 T/A of compost treatments produced the most rapid growth throughout the growing season.

Without added nitrogen (Table 15, Figure 23) average yield for 1969-71 increased in a curvilinear manner with increasing compost rates up to 50 T/A annually, but then decreased slightly. The 200 T/A rate of unscreened compost used in the first year prevented a sufficiently firm seedbed, so that the stand of plants was reduced about 10%. No stand problems resulted from screened compost used in subsequent years.

Response of corn to compost and nitrogen was also somewhat variable among treatments that differed little in the total amount of compost or nutrients supplied. Fertilizer nitrogen increased grain yields both in the presence and absence of 8 T/A of compost.

At the 50 T/A rate each ton of compost produced about 84 pounds of grain per ton of compost. This would have a value of about \$2. About 6 to 8 pounds of nitrogen appears to equal a ton of compost for corn production.

Studies of compost effects on moisture-holding capacity, bulk density, and nutrient content of the soil showed that the effects were very similar to those reported in Table 13 for the Muscle Shoals sorghum experiment.

Summary of Compost Utilization Research Projects. The data from experiments show that large tonnages of municipal compost can be applied on grassland or cropland and result in positive yield responses.

TABLE 15

RESPONSE OF CORN TO COMPOST, JOHNSON CITY EXPERIMENT

Treatment	1969 responses (per acre)			1970 responses (per acre)		
	Stalks	Ear Corn		Stalks	Ear Corn	
		Pounds	Bushels		Pounds	Bushels
1 - None	8230	3570	55	15,250	2615	37
2 - 80 lb N	8470	4960	76	15,250	4260	61
3 - 4T-Spring	8230	3235	49	15,000	3075	44
4 - 160 lb N	8230	4350	73	13,310	4090	58
5 - 8T-Spring	8710	4325	66	15,000	4015	57
6 - 8T-Fall	8230	3810	58	14,035	4090	58
7 - 4T-Fall	7745	3900	60	15,250	4600	66
8 - 8T-Spring + 80 lb N	8710	4900	75	13,795	4865	70
9 - 8T-Spring + 160 lb N	8470	5870	90	15,000	6220	89
10 - 8T-Fall	8230	3780	58	14,760	4260	61
11 - 50T-Fall	7745	4535	69	15,730	6825	97
12 - 100T-Fall	7745	4990	76	14,520	5760	82
13 - 200T-Fall	6775	4295	66	13,550	6120	87
LSD, 5% level	N.S.	855	13	N.S.	990	14

Compost contained 40% moisture; application rates are on a dry basis. Nitrogen was applied in spring as ammonium nitrate. Pounds and bushels of ear corn are on the basis of 15.5% moisture (70 pounds per bushel). The corn variety was Funk's G-5757.

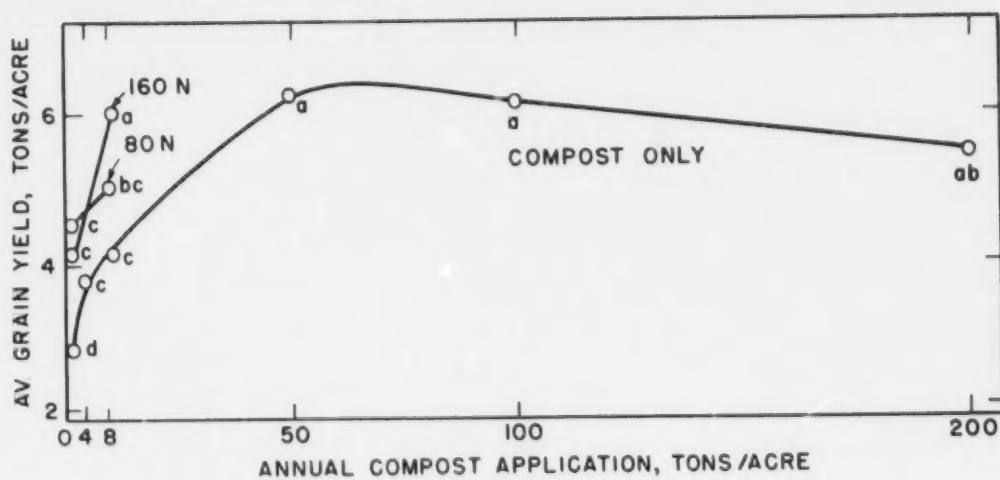


Figure 23. Three-year average corn yield, as affected by compost and nitrogen application. (Values having same letter are not significantly different at the 5% level).

Economic comparisons indicate that the actual value of compost in terms of crop response is only \$1 to \$2 per ton, with the value declining as the rate increased. Its monetary value is even less when compared to the value of chemical fertilizer needed to produce equivalent yields. Compost has favorable effects on the physical condition of the soil which cannot be achieved with fertilizer and which may be of economic value.

It is possible that the residual response to compost is such that an extremely long-term experiment would show sufficient cumulative benefits for the economics of its use to appear more favorable. However, the possible toxic effects of heavy metal accumulations must also be considered, although this problem may be alleviated by omitting sewage sludge from the compost process.

PROJECT INTEREST AND PUBLIC RELATIONS

The project attracted considerable interest from both technical and nontechnical individuals representing various organizations, all levels of government, foreign countries, and other entities. Records were maintained relative to visitors, requests for information, and other public relations aspects of the project. Accommodating visitors, processing requests, and carrying on associated functions consumed a significant amount of

time of the administrative and technical staff throughout the life of the project.

Visitors

The project received and accommodated approximately 1,000 visitors from July 1967 through June 1971. Many were from foreign countries (14 foreign countries represented) and many represented various levels of government (Appendix III).

Request for Information and Services

Request for information originated from varied sources. Many were from "VIP's," consultants, and municipal departments (i.e., planning commissions, health departments, sanitation departments, etc.) interested in the feasibility of windrow composting of municipal refuse (Appendix III). Requests made directly to this project for the report "Composting of Municipal Solid Waste in the United States" amount to approximately 300.

Compost samples were supplied to various investigators. The project also provided cooperative aid to a number of outside organizations. As an example, ground raw refuse was supplied to All American Environmental Control Corporation, Wilmington, Delaware for use in mushroom growing experiments. Union Carbide Corporation, Bound Brook, New Jersey requested aid in conducting plastic biodegradability tests. There were others throughout the life of the project.

The TVA Agriculturist provided compost to individuals other than the cooperators involved in demonstrations. During the spring of 1971, requests for compost received from individuals appeared to increase significantly over the preceeding year. During an eight-day period, 30 requests were received for compost. However, since the plant was ceasing operations on June 30, 1971, most requests could not be honored inasmuch as the compost was being stockpiled for demonstration and research projects during FY 1972 and beyond.

PROJECT TERMINATION

The four-year operation of the plant provided sufficient data to evaluate the feasibility of composting municipal refuse from health and economic standpoints, as well as to acquire information on the design and operation of the processing and handling equipment.^{1,3,4} Although various aspects of windrow composting such as "standards" development were identified as potential areas needing additional study, the basic objectives of the project were met. This circumstance, concurrent with the emergence of high priority solid waste research needs and limited funds, resulted in the decision to end support of the plant operations. Receiving of solid waste for processing was discontinued June 25, 1971.

TVA completed the final processing of the compost remaining on the field, and stockpiled the finished product to continue its research work. Research planned by TVA will seek to determine whether the compost produced at the plant can be used to increase production of tobacco, tomatoes, flowers, shrubbery, and other high-value specialty crops. The TVA Agriculturist will continue his evaluation of the demonstration sites which were established during the past two years.

While composting in the United States has suffered from poor economics, additional evaluation of its uses on selected soils and plants will help determine beneficial properties of the compost and potential monetary values not now available. Such data may enhance the value of compost and bring composting as a waste management technique into a more favorable position.

Perhaps the greatest potential application of compost is as an aid in reclaiming spoiled land areas such as those resulting from strip mining activities. While the cost of transporting the compost and applying it to the land may be high, potential benefits may justify the expense. Also potential exists for railhaul of refuse to strip mines and other spoiled land areas for composting and use of the compost on site. In addition, compost has many other potential applications as a soil amendment.

An unknown remaining with regards to the use of compost on lands, especially crop producing lands, is the question concerning application of toxic materials such as heavy metals contained in the compost. The potential for this happening is more with compost containing sewage sludge. The problem should not be ignored, however, with compost derived from other sources. What happens to these materials if they are leached to ground water or taken up by the plant and transmitted to animal and man is still unknown. While the hazard appears to be small, the problem must not be ignored.

REFERENCES

1. Stone, G. E., and C. C. Wiles. Interim report with operational data; Joint USPHS-TVA Composting Project, Johnson City, Tennessee, June 1967-September 1969. Environmental Protection Publication SW-31r.1of. [Cincinnati], U.S. Environmental Protection Agency, 1972. 212 p. [Restricted distribution.]
2. Personal communication. D. Milam, Rural Sanitation Service, Carter County, Tennessee, to C. C. Wiles.
3. Breidenbach, A. W., et al. Composting of municipal solid wastes in the United States. Environmental Protection Publication SW-47r. Washington, U.S. Government Printing Office, 1971. 103 p.
4. Duggan, J. C. Evaluation of compost demonstrations, August 1, 1969, to May 31, 1970. Muscle Shoals, Ala., Tennessee Valley Authority, Test and Demonstration Branch, Division of Agricultural Development.
5. Division of Research and Development, Bureau of Solid Waste Management. Unpublished data.
6. Personal communications. R. A. Carnes, Research Services, Office of Research and Monitoring, U.S. Environmental Protection Agency, to C. C. Wiles.
7. Boettcher, R. A. Air classification of solid wastes; performance of experimental units and potential applications for solid waste reclamation. Environmental Protection Publication SW-30c. Washington, U.S. Government Printing Office, 1972. 73 p.
8. Personal communications. Staff members, Horticultural Corps Research Center, North Carolina State University, Fletcher, North Carolina, to C. C. Wiles.
9. Mays, D. A., G. L. Terman, and J. C. Duggan. Municipal compost: effects on crop yields and soil properties. Journal of Environmental Quality, 2(1):89-92, Jan.-Mar. 1973.

APPENDIX I

APPENDIX I

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIESPer Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF JUNE		19 70		
Account Title				Account Number	Expense		Budget	Per Cent Expended
					This Month	Fiscal Year To Date		
USPHS-TVA Composting Plant								
<u>Delivery and Receiving</u>								
<u>Operation</u>				012-01.11				
11 - Salaries, ST	HRS	YTD			1,263	8,425		
	307.5	2125.0			181	372		
OT	33.0	71.5			230	1,483		
12 - Benefits								
Total salary expense					1,674	10,280		
26 - Supplies and materials					9	120		
Total					1,683	10,400		
<u>Maintenance</u>				012-01.12				
11 - Salaries, ST	15.0	355.5			78	1,665		
	OT	5.0	53.0		31	308		
12 - Benefits					14	305		
Total salary expense					123	2,278		
25 - Tire repairs, loader repairs					-	351		
26 - Supplies and materials					292	4,040		
Total					415	6,669		
Total Delivery and Receiving					2,098	17,069		
<u>Picking and Sorting</u>								
<u>Operation</u>				012-02.11				
11 - Salaries, ST	337.5	2414.0			1,260	8,670		
	OT	9.0	24.5		42	113		
12 - Benefits					224	1,433		
Total salary expense					1,526	10,216		
26 - Supplies and materials					29	166		
Total					1,555	10,382		
<u>Maintenance</u>				012-02.12				
11 - Salaries, ST	-	34.0			-	163		
	OT	-	27.0		-	147		
12 - Benefits					-	28		
Total salary expense					-	338		
26 - Supplies and materials					-	111		
Total					-	449		
Total Picking and Sorting					1,555	10,831		
<u>Grinding</u>								
<u>Rasper Operation</u>				012-03.11				
11 - Salaries, ST	29.0	809.5			130	3,363		
	OT	2.0	12.5		12	62		
12 - Benefits					24	576		
Total salary expense					166	4,001		
26 - Supplies and materials					-	-		
Total					166	4,001		

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

2
Per Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF		JUNE		19 70	
Account Title				Account Number	Expense		Budget	Per Cent Expended	
					This Month	Fiscal Year To Date			
<u>Grinding - Continued</u>				012-03.12					
<u>Rasper Maintenance</u>									
11 - Salaries, ST	HRS	YTD			-	616			
OT	-	128.5			-	197			
12 - Benefits	-	33.0			-	92			
Total salary expense					-	905			
26 - Supplies and materials					-	803			
Total				-	1,708				
<u>Hammermill Operation</u>				012-03.21					
11 - Salaries, ST	110.0	653.0			532	3,041			
OT	1.0	8.0			6	48			
12 - Benefits					97	566			
Total salary expense					635	3,655			
26 - Supplies and materials					44	89			
Total					679	3,744			
<u>Hammermill Maintenance</u>				012-03.22					
11 - Salaries, ST	3.0	178.5			16	913			
OT	2.0	5.0			12	30			
12 - Benefits					3	146			
Total salary expense					31	1,089			
26 - Hammers, belts, miscellaneous					293	1,818			
Total					324	2,907			
<u>Total Grinding</u>					1,169	12,360			
<u>Sludge Thickening and Mixing Operation</u>				012-04.11					
11 - Salaries, ST	2.0	139.5			9	575			
OT	-	3.5			-	16			
12 - Benefits					1	98			
Total salary expense					10	689			
26 - Supplies and materials					-	-			
60 - Truck use					-	8			
Total				10	697				
<u>Maintenance</u>				012-04.12					
11 - Salaries, ST	1.0	164.0			5	764			
OT	-	16.5			-	102			
12 - Benefits					1	135			
Total salary expense					6	1,001			
26 - Supplies and materials					10	720			
Total					16	1,721			
<u>Total Sludge Thickening and Mixing</u>					26	2,418			

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

3
Per Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF JUNE		1970	
Account Title			Account Number	Expense		Budget	Per Cent Expended
HRS	YTD	This Month		Fiscal Year To Date			
<u>Composting</u>			012-05.11				
<u>Hauling Operation</u>							
11 - Salaries, ST	178.5	1507.5		759	6,213		
OT	6.5	19.0		34	97		
12 - Benefits				138	1,099		
Total salary expense				931	7,409		
26 - Supplies and materials				-	3		
60 - Truck use				686	4,244		
Total			1,617	11,656			
<u>Hauling Maintenance</u>			012-05.12				
11 - Salaries, ST	-	106.5		-	523		
OT	-	5.0		-	30		
12 - Benefits				-	75		
Total salary expense				-	628		
26 - Supplies and materials				-	281		
Total			-	909			
<u>Turning and Wetting Operation</u>			012-05.21				
11 - Salaries, ST	224.5	1432.5		915	5,978		
OT	7.0	14.0		37	74		
12 - Benefits				145	1,019		
Total salary expense				1,097	7,071		
26 - Supplies and materials				203	711		
Total			1,300	7,782			
<u>Turning and Wetting Maintenance</u>			012-05.22				
11 - Salaries, ST	51.0	293.0		250	1,398		
OT	1.5	7.5		10	45		
12 - Benefits				45	237		
Total salary expense				305	1,680		
25 - Tire repairs, services				150	836		
26 - Supplies and materials				458	1,415		
Total				913	3,931		
<u>Total Composting</u>				3,831	24,278		
<u>Curing Operation</u>			012-06.11				
11 - Salaries, ST	8.0	146.0		35	616		
OT	-	3.5		-	19		
12 - Benefits				6	111		
Total salary expense				41	746		
26 - Supplies and materials				-	125		
60 - Truck use				-	22		
Total			41	893			

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

4
Per Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF JUNE		1970		
Account Title				Account Number	Expense		Budget	Per Cent Expended
HRS	YTD	This Month	Fiscal Year To Date					
<u>Curing - Continued</u>				012-06.12				
<u>Maintenance</u>								
11 - Salaries, ST	-	-	-		-			
OT	-	-	-		-			
12 - Benefits					-			
Total salary expense					-			
26 - Supplies and materials				15	47			
Total				15	47			
<u>Total Curing</u>					56	940		
<u>Regrinding and Screening</u>				012-07.11				
<u>Operation</u>								
11 - Salaries, ST	218.0	1782.0	934		7,763			
OT	8.0	27.0	43		147			
12 - Benefits			166		1,284			
Total salary expense			1,143		9,194			
26 - Supplies and materials			-	550				
60 - Truck use			274	2,579				
Total			1,417	12,323				
<u>Maintenance</u>				012-07.12				
11 - Salaries, ST	57.0	647.5	279		3,197			
OT	31.0	39.0	197		247			
12 - Benefits			51		559			
Total salary expense			527		4,003			
26 - Supplies and materials			622		1,302			
Total			1,149	5,305				
<u>Total Regrinding and Screening</u>					2,566	17,628		
<u>Hauling Rejects</u>				012-08.11				
<u>Operation</u>								
11 - Salaries, ST	257.5	1712.5	1,096		7,052			
OT	20.0	44.5	106		228			
12 - Benefits			199		1,240			
Total salary expense			1,401		8,520			
26 - Supplies and materials			-	15				
60 - Truck use			522	3,853				
Truck			1,923	12,388				
<u>Maintenance</u>				012-08.12				
11 - Salaries, ST	20.0	199.5	96		937			
OT	2.0	2.0	12		12			
12 - Benefits			17		125			
Total salary expense			125		1,074			
26 - Supplies and materials			-		309			
Total			125	1,383				
<u>Total Hauling Rejects</u>					2,048	13,772		

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

5
Per Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF JUNE		1970		
Account Title				Account Number	Expense		Budget	Per Cent Expended
HRS	YTD	This Month	Fiscal Year To Date					
<u>Disposal of Nonmarketable Processed Mat'l</u>				012-09				
11 - Salaries, ST	-	369.0	-		1,515			
OT	-	5.5	-		29			
12 - Benefits			-		271			
Total salary expense			-		1,815			
60 - Truck use			-12		246			
Total			-12		2,063			
<u>Distributing Processed Material</u>				012-10				
11 - Salaries, ST	19.0	683.5	85		2,900			
OT	1.5	36.5	8		190			
12 - Benefits			15		497			
Total salary expense			108		3,587			
26 - Supplies and materials, services			-		281			
60 - Truck use			-24		857			
Total			84		4,725			
<u>General Expense</u>								
<u>Operation of Grounds</u>				012-19.11				
11 - Salaries, ST	83.5	693.5	276		2,441			
OT	8.0	106.0	37		484			
12 - Benefits			35		299			
Total salary expense			348		3,224			
26 - Supplies and materials			-		83			
Total			348		3,307			
<u>Maintenance of Grounds</u>				012-19.12				
11 - Salaries, ST	5.0	40.0	21		177			
OT	-	3.0	-		17			
12 - Benefits			4		30			
Total salary expense			25		224			
26 - Supplies and materials			6		230			
60 - Truck use			-		20			
Total			31		474			
<u>Supervision</u>				012-19.21				
11 - Salaries, ST	251.0	2367.0	1,508		13,826			
OT	27.0	208.5	191		1,385			
12 - Benefits			280		2,423			
Total salary expense			1,979		17,634			
21 - Travel expense			54		413			
60 - Truck use			94		957			
Total			2,127		19,004			

STATEMENT OF OPERATIONS
DIVISION OF RESERVOIR PROPERTIES

6
Per Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF JUNE		1970	
Account Title	HRS	YTD	Account Number	Expense		Budget	Per Cent Expended
				This Month	Fiscal Year To Date		
<u>Processing Building Cleanup</u>			012-19.31				
11 - Salaries, ST	98.0	1731.0		375	6,460		
OT	3.0	56.5		14	268		
12 - Benefits				63	1,061		
Total salary expense				452	7,789		
26 - Supplies and materials				-	246		
Total				452	8,035		
<u>Office and Lab Expense</u>			012-19.41				
11 - Salaries, ST	14.0	481.5		47	1,858		
OT	-	49.0		-	280		
12 - Benefits				3	258		
Total salary expense				50	2,396		
25 - Contractual services				20	82		
26 - Supplies and materials				-	180		
60 - Trailer rental				38	766		
62 - Office equipment rental				22	152		
Total <u>1/</u>				130	3,576		
<u>Utilities</u>			012-19.51				
11 - Salaries, ST	34.0	138.0		177	689		
OT	-	1.0		-	7		
12 - Benefits				32	121		
Total salary expense				209	817		
23 - Power				943	5,509		
- Water				81	418		
- Telephone				21	286		
26 - Supplies and materials				370	836		
Total				1,624	7,866		
<u>Gasoline</u>			012-19.61				
26 - Gasoline purchases				713	2,614		
<u>Other</u>			012-19.71				
11 - Salaries, ST	- 292.5	1286.0		-1,269	5,671		
OT	2.5	45.5		14	244		
12 - Benefits				-233	983		
Total salary expense				-1,488	6,898		
21 - Travel				-	50		
22 - Freight				-	53		
26 - Supplies and materials				514	4,302		
60 - Truck use				7	153		
Total <u>2/</u>				-967	11,456		
Total General Expense				4,458	56,332		

1/ Includes \$1428 expended on baling experiment.

2/ Includes \$3915 expended on various experiments.

STATEMENT OF OPERATIONS

7

DIVISION OF RESERVOIR PROPERTIES

Per Cent of
F. Y. Expired 100

EASTERN		DISTRICT		MONTH OF JUNE		19 70		
Account Title				Account Number	Expense		Budget	Per Cent Expended
HRS		YTD	This Month		Fiscal Year To Date			
General Expense Distribution				012-20.61				
86 - Gas and oil issues to TVA					-202	-1,580		
Modification & Additions to Plant Equip.				012-50				
11 - Salaries, ST		410.5	3095.0		2,092	15,644		
OT		10.0	167.0		64	1,012		
12 - Benefits					380	2,637		
Total salary expense					2,536	19,293		
22 - Freight					-	133		
23 - Equipment rental					-	1,470		
25 - Contractual serv., Cobey aircond.					-	775		
26 - Supplies and materials					5,792	18,256		
31 - Equipment					1,352	3,579		
60 - Truck use					-	24		
82 - Suborder costs					-	-		
Total					9,681	43,531		
Activity Totals - USPHS-TVA Compost Plant				012				
11 - Salaries, ST, Ann.TL		2232.0	22902.5		10,128	101,071	105,755	96
Ann.SP		35.0	312.0		272	2,420	2,050	118
Hrly TL		175.0	2498.5		569	9,557	-	-
OT-Ann TL		180.0	1094.5		1,051	6,214	9,170	68
12 - Benefits					1,942	19,189	19,455	99
Total salary expense					13,962	138,451	136,430	101
21 - Travel					54	463	500	93
22 - Freight					-	187	200	94
23 - Telephone, util.					1,045	6,212	6,000	104
Equipment rental					-	1,470	1,500	98
25 - Other services					282	2,693	3,000	90
26 - Supplies and materials					9,224	38,772	30,500	127
31 - Equipment					1,356	3,583	3,000	119
60 - Transp. Branch equip. use					1,584	13,732	14,560	94
62 - Office equipment use					22	154	150	103
66 - Reproduction					-	13	-	-
70 - Warehouse issues					31	216	240	90
82 - Transferred costs					-	-	3,920	-
Gross					27,560	205,946	200,000	103
86 - Distribution				012-20	-202	-1,579	-2,000	79
Expenditures					27,358	204,367	198,000	103
50 - Income				012-999	-27,358	-204,367	-198,000	103
Net					-	-	-	-

STATEMENT OF OPERATIONS

USPHS - TVA COMPOSTING PROJECT

Percent of
F. Y. Expired 100

			MONTH OF		JUNE		1971	
Account Title	HRS	YTD	Account Number	Expense		Budget	Percent Expended	
				This Month	Fiscal Year To Date			
<u>RECEIVING AND PRIMARY PROCESSING</u>								
11 - Salaries, ST	404.0	5641.0	72-01	1,670.81	22,766.19			
OT	-	90.5		-	515.48			
12 - Benefits				227.50	3,846.03			
Total salary expense				1,898.31	27,127.72			
26 - Supplies and materials				-	50.32			
Total				1,898.31	27,178.04			
<u>GRINDING</u>								
11 - Salaries, ST	160.0	2576.5	72-03	751.77	12,005.88			
OT	-			-	22.00			
12 - Benefits				126.00	2,104.80			
Total salary expense				877.77	14,132.68			
26 - Supplies and materials				-	648.33			
Total				877.77	14,781.01			
<u>SLUDGE THICKENING AND MIXING</u>								
			72-04	-	-			
<u>COMPOST PROCESSING</u>								
11 - Salaries, ST	309.0	3508.5	72-05	1,470.33	15,956.73			
OT	4.5	45.0		26.29	244.32			
12 - Benefits				278.09	2,970.19			
Total salary expense				1,774.71	19,171.24			
26 - Supplies and materials				54.27	560.03			
60 - Truck use				757.62	6,677.82			
70 - Warehouse issues				-	23.64			
Total				2,586.60	26,432.73			
<u>REGRINDING AND SCREENING</u>								
11 - Salaries, ST	571.0	2831.0	72-07	2,708.96	12,424.95			
OT	40.5	105.0		247.19	625.00			
12 - Benefits				500.60	2,272.17			
Total salary expense				3,456.75	15,322.12			
23 - Equipment rental				50.00	150.00			
25 - Repairs				-	4.50			
26 - Supplies and materials				157.00	1,385.98			
60 - Truck use				33.12	654.90			
Total				3,696.87	17,517.50			
<u>HAULING REJECTS</u>								
11 - Salaries, ST	129.0	1728.0	72-08	610.37	7,812.19			
OT	-	25.5		-	141.40			
12 - Benefits				115.44	1,468.93			
Total salary expense				725.81	9,422.52			
26 - Supplies and materials				-	13.95			
60 - Truck use				385.02	3,823.23			
Total				1,110.83	13,259.70			

STATEMENT OF OPERATIONS

2

USPHS - TVA COMPOSTING PROJECT

Percent of
F. Y. Expired 100

MONTH OF JUNE 19 71

Account Title	HRS	YTD	Account Number	Expense		Budget	Percent Expended
				This Month	Fiscal Year To Date		
<u>UTILIZATION AND DEMONSTRATIONS</u>							
11 - Salaries, ST	9.0	2462.0	72-10	47.02	13,821.09		
OT	-	61.5	41-020	-	340.48		
12 - Benefits				8.89	2,357.68		
Total salary expense				55.91	16,519.25		
21 - Travel				-	282.26		
22 - Freight				-	18.87		
23 - Communications				-	28.00		
25 - Contractual services, equip. rental				-	112.50		
26 - Supplies, services				299.74	407.78		
60 - Truck use				161.46	2,445.24		
Total				517.11	19,813.90		
<u>PLANT EQUIP. & GROUNDS MAINTENANCE</u>							
11 - Salaries, ST	620.0	4908.5	72-11	3,013.04	23,980.49		
OT	88.0	263.0		542.10	1,608.90		
12 - Benefits				471.06	4,156.03		
Total salary expense				4,026.20	29,745.42		
23 - Equipment rental				-	41.00		
25 - Contractual services				187.24	1,502.37		
26 - Supplies and materials				989.75	10,320.87		
31 - Equipment purchased				-	235.58		
60 - Truck use				8.28	26.91		
70 - Warehouse issues				-	25.20		
Total				5,211.47	41,897.35		
<u>GENERAL PROJECT EXPENSES</u>							
<u>Supervision</u>							
11 - Salaries, ST	264.0	2312.0	72-19.1	1,709.99	14,433.11		
OT	41.0	179.5		312.08	1,294.77		
12 - Benefits				324.27	2,666.61		
Total salary expense				2,346.34	18,394.49		
26 - Supplies and materials				-	5.00		
60 - Truck use				128.46	810.34		
Total				2,474.80	19,209.83		
<u>Office and Lab Expense</u>							
11 - Salaries, ST	2.0	176.0	72-19.2	7.55	651.37		
OT	-	4.0		-	19.74		
12 - Benefits				.94	79.07		
Total salary expense				8.49	750.18		
25 - Contractual services				-	103.00		
26 - Supplies and materials				20.00	26.00		
60 - Trailer rental				68.00	795.60		
62 - Office equipment rental				12.25	147.15		
Total				108.74	1,821.93		

STATEMENT OF OPERATIONS
USPHS - TVA COMPOSTING PROJECT

3
Percent of
F. Y. Expired 100

				MONTH OF		JUNE		1971	
Account Title				Account Number	Expense		Budget	Percent Expended	
					This Month	Fiscal Year To Date			
HRS				YTD					
<u>Utilities</u>									
23 - Power				72-19.3	565.41	6,364.70			
- Water					83.05	968.34			
- Telephone					22.27	266.75			
Total					670.73	7,599.79			
<u>Travel</u>									
21 - Travel (per diem)				72-19.4	61.21	391.34			
60 - Car expense					57.17	240.91			
Total					118.38	632.25			
<u>Other</u>									
11 - Salaries, ST				72-19.5	-1,911.21	836.88			
OT					25.56	136.27			
12 - Benefits					-366.38	152.30			
Total salary expense					-2,252.03	1,125.45			
25 - Contractual services					-	21.54			
26 - Supplies and materials					848.36	3,753.92			
- Gasoline and oil					956.88	3,981.61			
60 - Truck use					40.50	131.38			
70 - Warehouse issues					-	67.72			
Total					-406.29	9,081.62			
Total General Project Expenses					2,966.36	38,345.42			
<u>General Expense Distribution</u>									
86 - Gas and oil issues to TVA				72-20.5	-147.73	-1,973.41			
<u>SPECIAL PROJECTS</u>									
				72-40.1	-	-			
<u>MODIFICATIONS & ADDITIONS TO PLANT & EQUIP.</u>									
<u>Used 5-Ton GMC Dumpster Truck & Containers</u>									
11 - Salaries, ST				72-50		1,227.07			
OT						13.00			
12 - Benefits						232.09			
Total					-	1,472.16			
22 - Freight						74.61			
25 - Repair services, crating equip.						360.51			
26 - Repair parts						653.55			
26 - Truck purchase price						495.00			
31 - Dumpster container purchase price						450.00			
Total					-	3,505.83			

STATEMENT OF OPERATIONS

4

USPHS - TVA COMPOSTING PROJECT

Percent of
F. Y. Expired 100

MONTH OF JUNE 1971

Account Title	HRS	YTD	Account Number	Expense		Budget	Percent Expended
				This Month	Fiscal Year To Date		
<u>Belt Conveyor #8</u>							
11 - Salaries, ST	-	69.0	72-51		361.34		
OT	-	-			-		
12 - Benefits					69.23		
Total salary expense				-	430.57		
26 - Supplies and materials					34.86		
Total				-	465.43		
<u>Scalper</u>			72-52				
11 - Salaries, ST	-	819.0			4,239.37		
OT	-	2.5			16.00		
12 - Benefits					805.33		
Total salary expense				-	5,060.70		
23 - Equipment rental					101.25		
26 - Supplies and materials					863.16		
Total				-	6,025.11		
<u>Air Classifier</u>			72-53				
11 - Salaries, ST	-	309.0			1,632.41		
OT	-	-			-		
12 - Benefits					301.94		
Total salary expense				-	1,934.35		
23 - Crane rental					112.50		
25 - Repair services					123.49		
26 - Supplies and materials					876.43		
Total				-	3,046.77		
<u>Belt Conveyor #9</u>			72-54				
11 - Salaries, ST	-	62.0			327.99		
OT	-	-			-		
12 - Benefits					62.04		
Total salary expense				-	390.03		
26 - Supplies and materials					719.26		
Total				-	1,109.29		
<u>Belt Conveyor #10</u>			72-55				
11 - Salaries, ST	-	76.0			426.62		
OT	-	-			-		
12 - Benefits					80.69		
Total salary expense				-	507.31		
26 - Supplies and materials					714.19		
Total				-	1,221.50		

STATEMENT OF OPERATIONS
USPHS - TVA COMPOSTING PROJECT

Percent of
F. Y. Expired 100

				MONTH OF		JUNE		19 71	
Account Title HRS YTD				Account Number	Expense		Budget	Percent Expended	
					This Month	Fiscal Year To Date			
ACTIVITY TOTALS									
11 - Salaries, ST. Ann. TL 1607.0 24135.0					8,201.55	115,235.09	116,915	99	
Ann. SP 32.0 1222.0					279.57	9,091.57	18,060	50	
Hrly. TL 450.0 2541.5					1,597.51	8,577.02	8,100	106	
OT 178.0 811.0					1,153.22	4,977.36	3,670	136	
					1,686.41	23,625.15	25,910	91	
12 - Benefits					12,918.26	161,506.19	172,655	94	
Total salary expense					61.21	673.60	800	84	
21 - Travel					-	93.48	100	93	
22 - Freight					720.73	8,082.54	6,000	135	
23 - Telephone, util., equip. rental					187.24	2,165.41	2,000	108	
25 - Other services					3,326.00	25,522.74	28,600	89	
26 - Supplies and materials					-	685.58	570	120	
31 - Equipment					1,639.63	15,606.33	15,000	104	
60 - Transp. Branch equip. use					12.25	147.15	150	98	
62 - Office equipment use					-	-	400	-	
66 - Maps & reproduction					-	116.56	100	117	
70 - Warehouse issues					-	-	625	-	
82 - Shop, lab., and other					18,865.32	214,599.58	227,000	95	
Gross					-147.73	-1,973.41	-2,000	99	
- Distribution				72-20	18,717.59	212,626.17	225,000	95	
Net direct expenditures					2,159.76	22,411.90	18,000	125	
Overheads					20,877.35	235,038.07	243,000	97	
Total Expenditures					-20,877.35	-235,038.07	-243,000	97	
50 - Income				72-999	-	-	-	-	
Net*					-	-	-	-	

APPENDIX II

TECHNICAL REPORT ON JOHNSON CITY BALING EXPERIMENT

Technical Details

A. Quantity, Weight, and Size of Bales Produced

1. Table II-1 is a listing of the bales produced by serial number. Included are their weights, the moisture measured from refuse samples taken as the bale was produced, density, volume, and other remarks. Table II-2 is a list of bales according to their quality (premium, good, poor, etc.).

2. An attempt was made to account for all the raw incoming refuse to the compost plant in terms of the total weight of bales produced during the same period. The following is a material balance made during the period of 1/19/70 through 1/27/70 over which time the baling occurred.

Refuse in pit at start of test on 1/19/70	15 tons
Raw refuse received during baling test	208 tons
"Rejects" or "noncompostables" removed from refuse	-8 tons
Refuse left in pit area at end of test	35 tons
Pit balance (35 - 15)	-20 tons
Total tonnage processed	180 tons
Total weight of bales produced (This includes an estimated weight for broken bales.)	133 tons
Unaccounted for	47 tons

A large amount of spillage occurred at various points, such as the conveyors, extruding material from the baler, material needed to "fill" the baler before making good bales, and miscellaneous wastes. This total spillage was not weighed, but it was estimated to be between 10 and 15 tons. Another consideration is that there was some weight loss through vaporization during grinding. At Center Hill facility, water loses of up to 6 percent (or 11 tons, in this case) have been measured under certain conditions. There is a possibility that the tonnage estimated in the pit before and after the experiment was in error or that the scale was in error though the latter was discounted.

B. Details on Baling Machine

1. The baling machine used in the study was a model 12375 high-pressure solid waste baler manufactured by the American Baler Company of Bellevue, Ohio. The machine has a shipping weight of 33,000 pounds and sells for \$42,000 (1970). The nominal bale size produced is 30 inches by 40 inches by 72 inches, or approximately 50 cubic feet. A 150 horsepower electric motor powers the main hydraulic system which consists of a single 12-inch diameter hydraulic piston mounted horizontally. The machine has been adapted from the company's paper baling design which is similar in concept to a conventional hay or straw baling machine. The refuse must be shredded before

this machine can handle it. The compaction effort applied on the refuse is approximately 330 pounds per square inch. This pressure is supplied by 3,000 psi of oil pressure acting in a 12 inch diameter hydraulic cylinder. Each bale is tied with five 1/8 inch diameter steel wires. The wire tying is accomplished by hand. Two men are required to run the machine and tie wires. A third man is to handle the bales.

Cost Estimate for Baling (less shredding)

Steel tie wire	\$.30
Labor, 3 men at \$3.50 per hr.	.42 to 1.00 per ton (10.5 to 25 tons/hr.)
Electricity	<u>.06</u>
Total	\$.78 to 1.36 per ton

The baler can handle 250 to 600 tons of refuse per 24 hours.

C. Character of the Baled Refuse

1. The material used for the baling experiment was the normal municipal refuse received at the Johnson City compost plant. It is solid waste from the Johnson City area. The following data were taken in order to describe the baled refuse:

- a. Weight of the incoming material
- b. Visual 35 mm color pictures of the incoming material.
- c. The weight of rejects.* Rejects were removed in the

*Total weight of rejects for bales 1-20: 26 percent of incoming refuse weight
Total weight of rejects for bales 21-83: 1 to 2 percent of incoming refuse weight

normal manner with hand picking and magnetic separation up through bale number 20. Starting with bale number 21, a special wiper was used to cancel the effect of the magnetic separator so that all tin cans and most of the metallic materials were ground and baled. Heavy steel items and nongrindable items were removed by hand.

d. The refuse was hammermilled with the Model 48.4 Gruendler machine. This unit is 53 inches wide and the serial number is 2112. The grinder has a 250 horsepower 1,175 rpm motor. The grates used in the study were the normal combination of 2" and 3" openings used when making compost for bales numbers 1 through 20. Starting with bale number 21, the grates were rearranged to give 3" and 4" openings. The Door-Oliver Rasper was not used because its holes would plug with tin cans.

e. Several 500-gram (approximately) samples of the ground refuse were taken at the baler hopper. These samples were associated with a particular bale serial number. They were used for moisture determination and other analysis as follows:

- particle size
- metal content
- glass content

-total cellulose

-moisture (samples dried at 100°C for 16 to 20 hours)

The moisture values are given in Table II-1. The remaining data will be reported later by research services.*

D. Miscellaneous Problems Encountered

1. Moisture - The moisture content of the ground refuse presented perhaps the largest problem in baling. As long as the moisture stayed in the range of 20 percent to about 35 percent or 40 percent, the baling machine worked very well. However, when the moisture content exceeded 40-45% the refuse was extruded from the open sides of the bale chamber. Overall, the moisture probably averaged 30 percent or 35 percent, but the occasional wet batch with 45 percent or 55 percent of moisture would cause an extrusion to occur. The baling pressure would then have to be reduced until the extruded zone was pushed out of the machine. There is a possibility that the sides of the baling chamber could be more completely enclosed to reduce this tendency to extrude.

2. Bale Tie Wires - The baler operators occasionally could not get all five 1/8 inch steel tie wires wrapped around

*Table II-3 - "Percent Composition By Weight" is an exact excerpt from a memo from Israel R. Cohen, Research Services Laboratory, to D. A. Oberacker, reporting the results of the analysis, dated March 24, 1970.

the bale. This was usually due to an obstruction such as a piece of metal in the wire guide channels in the rubber bale separator blocks. Occasionally, a bale would be formed with all five wires, but a wire or two would snap due to excess tension after it left the machine. This is apparent a matter of technique as to how tight to tie the wire.

3. Bales Attacked by Birds - During periods when the ground was covered with snow, large flocks of birds (starlings) would cover the bales and vigorously attack them in search of food. Pictures were taken to record the effect of a few hours of bird feeding on the bales. The birds would round out the edges and roughen up the sides of the bales. Portions of the sides of the bale would be scattered around the ground adjacent to the bales. The birds disappeared when the snow melted.

4. Weather Conditions - A wide variety of weather conditions was encountered during the baling project. Temperatures ranged from 50°F down to -20°F. The baler itself did not appear to be affected by temperature. When the temperature dropped below 15°F the refuse arrived in a frozen condition. The frozen refuse did not compact to as high a density as unfrozen refuse.

5. Bale Perishability - While under pressure in the baling chamber the density of the bales was calculated to be as high as 80 lbs/cu. ft. Upon release from the chamber the material

began to expand and to flake off at the edges of the bale. Handling and transporting contributed damage to the bales. Sometimes composting set in and the bales dried out, contributing to the loss of weight and shape.

6. Compost Baling Test - One brief attempt was made to bale finished unscreened compost. The moisture content was in the range of 60 percent (by wet weight) and the compost extruded from the open sides of the machine. The extrusion was so extensive that no satisfactory bales were produced.

Future Recommendations

- A. Check accuracy of scale at Johnson City.
- B. Restack the bales according to grade (reference Table II-2).
- C. Cover bales with tarpaulin for protection from weather and birds.
- D. Check temperatures within bales with a temperature probe.
- E. Steel strapping should be added to the bales to increase their stability for shipping. Perhaps restrapping, reweighing, and loading on a trailer for shipping could be done in one operation to save wear and tear on the bales.

—DONALD A. OBERACKER

Acting Chief, Processing Section
Division of Research and Development
Bureau of Solid Waste Management

(Note: These recommendations made at the time of the departure of the engineer were later carried out.)

Reference: Trip Report dated February 5, 1970, Johnson City, Tennessee Composting Plant, Baling Experiment, January 15-28, 1970.

Memo dated December 22, 1969, Proposed Refuse Grinding and Baling at Center Hill Laboratory. Sent to Acting Chief, Sea Disposal Section; from Donald Oberacker.

TABLE II-1
REFUSE BALE LOG - JOHNSON CITY, TENNESSEE COMPOST PLANT, AMERICAN 12,000 SERIES BALES

Bale Serial No.	Bale Net Weight Lbs.	% H ₂ O Based on Dry Wt.	% H ₂ O Based on Wet Wt.	Calculated Bale Volume cu. ft.	Calculated Bale Density lb/cu. ft.	Remarks
1	2340	51.9	34.2	43.3	54.1	
2	2300			36.4	63.1	very poor - ends crooked
3	2560			45.7	56.0	4 wires but fair
4	3280			54.5	60.1	good
5	2920	49.6	33.2	46.2	63.2	good
6	3040			44.9	67.9	good
7	--	112.7	52.8	--	--	bale fell apart - bulged out
8	3080	36.5	26.7	53.9	57.2	4 wires - fair
9	3540			60.4	58.6	has five wires but top one slipped down - still good
10	2825			46.8	60.5	poor - 4 wires
11	3045			51.7	59.0	very good
12	3060			52.5	58.4	very good
13	2275			54.4	41.9	poor - weighing delayed, fell off baler - 4 wires
14	3385			58.6	57.8	3 wires but fair
15	4000	56.6	36.2	62.3	64.2	4 wires but good
16	3315			53.6	61.9	

TABLE II-1 (cont'd.)
REFUSE BALE LOG - JOHNSON CITY, TENNESSEE COMPOST PLANT, AMERICAN 12,000 SERIES BALER

Bale Serial No.	Bale Net Weight Lbs.	% H ₂ O Based on Dry Wt.	% H ₂ O Based on Wet Wt.	Calculated Bale Volume cu. ft.	Calculated Bale Density lb/cu. ft.	Remarks
17	3075			46.9	65.6	
18	3345			50.8	65.9	4 wires but good
19	3410			58.0	58.9	excellent - tag hidden
20	3050			50.4	60.6	very good
21	2325	35.8	26.4	45.4	51.3	fell off baler, but otherwise good, first containing coarse grind and metals
22	2310	43.0	30.0	48.5	47.6	very good
23	2295			53.1	43.2	fell off baler, braised, 4 wires, but still good looking
24	2360	36.3	26.6	48.4	48.8	4 wires, 1 loose, but good
25	--					cracked open, two wires broke, scrap
26	2490			48.3	51.6	4 wires but good
27	--	37.6	27.3			cracked open, two wires broke, scrap
28	2150			54.6	56.4	2 loose wires but good
29	3080			54.6	56.4	very good, 1 slipped wire
30	2680	48.1	32.5	48.2	55.6	4 wires but good
31	2680			50.4	58.3	4 wires but good
32	2840			50.0	56.9	very good

TABLE II-1 (cont'd.)
REFUSE BALE LOG - JOHNSON CITY, TENNESSEE COMPOST PLANT AMERICAN 12,000 SERIES BALER

Bale Serial No.	Bale Net Weight Lbs.	% H ₂ O Based on Dry Wt.	% H ₂ O Based on Wet Wt.	Calculated Bale Volume cu. ft.	Calculated Bale Density lb/cu. ft.	Remarks
33	2660			46.9	56.8	4 wires, 1 loose, but good
34	3060	37.1	27.1	51.9	59.1	1 loose wire but very good
35	2900			49.9	58.2	4 wires, 1 loose, but good
36	2710			47.0	57.6	excellent
37	2890			48.2	60.0	excellent
38	2910			47.6	61.0	4 wires but very good
39	2495			44.9	55.6	contains conveyor belt area times 2 inches (came out to be 8" to 10" of bale length) of snow
40	3060	35.6	26.0	52.0	58.9	4 wires but good
41	2200			50.1	41.3	very good (wrong weight)
42	3300	43.9	30.5	54.2	60.9	excellent
43	3070	31.9	24.1	50.9	60.5	very good
44	2870			49.5	58.0	4 wires but good
45	2700			48.4	55.9	very good
46	2870			50.25	57.1	4 wires but good
47	3070			52.8	58.2	4 wires but good
48	3810			56.2	67.8	was very good - now good - fell off stack

TABLE II-1 (cont'd.)

REFUSE BALE LOG - JOHNSON CITY, TENNESSEE COMPOST PLANT AMERICAN 12,000 SERIES BALER

Bale Serial No.	Bale Net Weight Lbs.	% H O Based on Dry Wt.	% H O Based on Wet Wt.	Calculated Bale Volume cu. ft.	Calculated Bale Density lb/cu. ft.	Remarks
49	4010	68.5	40.7	57.5	69.8	very good
50	3710			57.2	64.8	bulgy sides but good
51	3610			55.8	64.7	very good
52	3335			49.8	67.0	very good
53	3570			55.7	64.0	three wires - fair - arched
54	3680			52.3	70.4	4 wires but good
55	3660			58.0	63.1	4 wires but good
56	3940			59.4	66.4	3 wires
57	3590	47.3	32.0	55.6	64.5	1 wire slipped - very good
58	3310			51.6	64.1	3 wires plus 1 slipped wire
59	3610			53.4	67.7	very good
60	3590	40.1	28.6	52.5	68.4	very good
61	4140			59.3	69.8	4 wires
62	3350			48.75	68.6	very good
63	3520	55.5	35.6	55.6	63.4	4 wires but good
64	3150			49.0	64.4	4 wires but good
65	3040	44.1	30.6	50.0	61.2	4 wires but good

TABLE II-1 (cont'd.)

REFUSE BALE LOG - JOHNSON CITY, TENNESSEE COMPOST PLANT AMERICAN 12,000 SERIES BALER

Bale Serial No.	Bale Net Weight Lbs.	% H O Based on Dry Wt.	% H O Based on Wet Wt.	Calculated Bale Volume cu. ft.	Calculated Bale Density lb/cu. ft.	Remarks
66	3370			54.3	62.1	4 wires, 1 slipped wire
67	3360			52.9	61.6	4 wires but good
68	3210			52.9	60.8	4 wires, 1 slipped wire
69	3660	29.2	22.6	54.0	67.5	
70	3530			55.7	63.4	4 wires but very good
71	3030			45.4	66.0	77.1 lb/cu. ft. while in baler
72	3400			50.0	68.0	4 wires but very good
73	3820	67.6	*40.4	54.1	70.6	1 wire slipped but very good
74	3650			49.9	71.2	very good
75	3150			47.9	65.9	1 wire slipped
76	3830			55.8	68.6	3 wires - fair
77	3150			47.4	66.5	4 wires
78	3250	40.5	28.9	48.3	67.4	4 wires
79	3070			48.8	63.0	3 wires
80	3170			48.6	65.2	4 wires
81	3880			56.3	69.0	4 wires
82	3020			45.4	66.6	1 wire slipped
83	3190			46.6	68.4	3 wires but equally spaced
						very good

TABLE II-2
DENSITY OF BALES

PREMIUM GRADE bales with 64.0 lbs/cu ft or over		GOOD bales with 58.0 to 63.99 lbs/cu ft		POOR bales with less than 58 lbs/cu ft	
Bale Nos.		Bale Nos.		Bale Nos.	
6	52 61 75	2	19 42 67	1	24 39
15	53 62 76	4	20 43 68	3	26 41
17	54 64 77	5	31 44 70	8	28 45
18	56 69 78	9	34 47 79	13	29 46
48	57 71 80	10	35 55	14	30
49	58 72 81	11	37 63	21	32
50	59 73 82	12	38 65	22	33
51	60 74 83	16	40 66	23	36
PREMIUM GRADE - 32 bales		GOOD - 28 bales		POOR - 20 bales	

BROKE APART - 3 bales
7 25 27

TABLE II-3

PERCENT COMPOSITION BY WEIGHT

Component	Lab Sample #1	Lab Samples #2-6	Lab Samples #7-22
Paper - 3 sq. in and larger	11.5	1.1	7.0
Paper - 3/8" - 4 sq. in.	37.5	51.6	31.2
Food & Fine Organic	22.5	22.3	29.6
Textiles	14.9	6.8	4.5
Plastics	2.6	1.3	1.9
Wood	0.2	0.4	0.2
Metals & Foil	5.1	2.1	7.5
Ceramic & Misc.		3.0	1.2
Glass	5.7	10.4	15.1
TOTAL	100.0	99.0	98.2

APPENDIX III

VISITORS TO COMPOSTING PROJECT JOHNSON CITY, TENNESSEE

States

Alabama	Mississippi
California	Missouri
Colorado	New Jersey
Connecticut	New York
Delaware	North Carolina
District of Columbia	Ohio
Florida	Oklahoma
Georgia	Pennsylvania
Indiana	South Carolina
Iowa	South Dakota
Kentucky	Tennessee
Louisiana	Texas
Maryland	Virginia
Massachusetts	Washington
Michigan	West Virginia
Minnesota	Wisconsin

Foreign Countries

Australia	India
Canada	Mexico
Czechoslovakia	Nigeria
England	South Africa

Ethiopia

Sweden

Germany

Switzerland

Holland

Taiwan

Groups

A group of approximately ten teachers from the Johnson City School system accompanied by City Manager, James M. Mosier, toured the plant as part of their pre-school orientation.

Twenty-four students from the In-Service Sanitarian School of East Tennessee State University.

Nine students of the College of Health, East Tennessee State University.

Forty-eight in-service sanitarians from East Tennessee State University.

Twenty-nine science and biology students from Elizabethtown High School.

Ten East Tennessee State University geology students.

Approximately twenty-five members of the Upper East Tennessee Soil Conservation Service.

Forty-three students from the College of Health, East Tennessee State University.

Twelve students from the Environmental Health Class, East Tennessee State University with their instructor.

The Protector Environmental Club, composed of eleven students and two teachers from North Junior High School, Johnson City.

Eleven biology students from Clinch Valley College, Wise, Virginia, with their instructor.

Thirty-two biology students from Elizabethton High School,
accompanied by their teacher.

Thirty-four fourth grade students from University High.

Five students from the Health Science Department of East
Tennessee State University, accompanied by their instructor.

State Solid Waste Directors from Regions III and IV
Program Review, Johnson City.

Participants from OSWM Training Course in Composting Methods,
ETSO.

REQUESTS FOR INFORMATION ON COMPOSTING

Foreign

Bridgetown, Barbados	Terra Nova, B. C.
Santo Domingo, R. D.	Vienna, Austria
Parkes, New South Wales, Australia	Bilbai, Spain
Bankok, Thailand	Baroda, India
The Hauge, Holland	Bombay, India
Bogota, D. E. Columbia	Munich, Germany
Vancouver, B. C. Canada	Sarnia, Ontario, Canada
Varkaus, Finland	Birmingham, England
Kuala Lumpur, Malaysia	Poona, India
Pandung, Indonesia	Powell River, B. C. Canada
Toronto, Ontario, Canada	Stockholm, Sweden
British Embassy	Saskatoon, Sask., Canada
Wexford, Ireland	Malenfield Gr., Switzerland
Haellabrottet, Sweden	Sarnia, Ontario, Canada

Journals and Publications

Refuse Removal Journal	New York, New York
Town & Country Shopper	Boulder, Colorado
The American City Magazine	Pittsfield, Massachusetts

Universities & Colleges & Other Schools

Manhattan College	Bronx, New York
University of Georgia	Athens, Georgia

Oregon State University	Corvallis, Oregon
Washington University	St. Louis, Missouri
Georgia Inst. of Technology	Atlanta, Georgia
New York State College of Agriculture	Ithaca, New York
Harvard Engineering Laboratory	Cambridge, Massachusetts
Institute of Technology	Bandung, Indonesia
North Carolina State University	Raleigh, North Carolina
University of Michigan	Ann Arbor, Michigan
School of Public Health	Chapel Hill, North Carolina
Hollins College	Hollins, Virginia
University of Birmingham	Birmingham, England
Rollins College	Winger Park, Florida
Columbia University	New York, New York
East Tenn. State University	Johnson City, Tennessee
Lehigh University	Bethlehem, Pennsylvania
Cornell University	Ithaca, New York
Rutgers University	New Brunswick, New Jersey
University of British Columbia	Vancouver, B. C. Canada
Northwestern University	Evanston, Illinois
Claremont College	Claremont, California
Principia College	Elsah, Illinois
University of Tennessee	Knoxville, Tennessee
The Arthur E. Premm School	Oakdale, New York
Clarendon Junior High	Clarendon, Texas

Congressmen and Legislators

Honorable Jack Brooks

Senator Everette Dirksen

Congressman James H. Quillen

United States (Individuals)

Fort Smith, Arkansas

Newport, Arkansas

Meadow View, California

Vandenberg AFB, California

Porterville, California

Maitland, Florida

Boca Raton, Florida

Atlanta, Georgia

Decatur, Georgia

Kaneohe, Hawaii

Evanston, Illinois

Indianapolis, Indiana

Owensburg, Kentucky

Lexington, Kentucky

Hebron, Kentucky

Metairie, Louisiana

Natchitoches, Louisiana

Quincy, Massachusetts

Harwich, Massachusetts

Baltimore County, Maryland

Honorable Charles S. Gubser

Honorable Howard W. Cannon

Representative James Fulton

Twenty-nine Palms, California

Sacramento, California

Westbury, Connecticut

Casselberry, Florida

Pensacola, Florida

Ossining, New York

Plymouth, North Carolina

Columbus, Ohio

Tiffin, Ohio

Cottage Grove, Oregon

Lemont, Pennsylvania

Renfrew, Pennsylvania

Valencia, Pennsylvania

Greeneville, Tennessee

Johnson City, Tennessee

Lavinia, Tennessee

Morristown, Tennessee

Dallas, Texas

Longview, Texas

Garland, Texas

Dowagiac, Michigan

Reno, Nevada

Bound Brook, New Jersey

Iceland, Suffolk County, New York

New York, New York

Consultants

Kramer, Comer & Passe

Plastic Engineering, Inc.

W. E. Parfitt & Associates, Inc.

Greeley and Hansen, Engineers

Engineering International Corp.

Near East South Asia Engrs.

Manganaro, Martin, & Lincoln, Engrs.

Associated Engineering Services, Ltd.

A. Ahlstrom Osakeythio

George C. Sell & Associates, Inc.

Whitman, Requardt & Associates

Dayton & Knight, Ltd.

A. L. Verdonck, Prof. Engineer

Bowe, Walsh & Associates

Lawrence Halprin & Associates

Dr. C. L. Mantell, Consulting
Chemical Engineer

Putney, Vermont

Grundy, Virginia

Radford, Virginia

Richmond, Virginia

Charleston, West Virginia

For

Miami County, Ohio

Bridgetown, Barbados

San Juan, Puerto Rico

New York-Chicago

The Hague, Holland

Agency for International Development

Danbury, Connecticut

Vancouver, B. C.

Varkaus, Finland

Chicago, Illinois

Baltimore, Maryland

Terra Nova, B. C.

Sarnia, Ontario, Canada

Huntington, New York

San Francisco, California

Manhasset, New York

Malcolm Pirnie, Inc.	Paramus, New Jersey
Green Engineering Company	Sewickley, Pennsylvania
Gore & Storrie, Consulting Engrs.	Toronto, Canada
Rochester Engr. Society's Recycling of Solid Waste Committee	Rochester, New York
Concentrie Engineering Company	Dallas, Texas
Heyl & Patterson	Pittsburg, Pennsylvania
Steve Julius, Consulting Engrs. for Stevenson, Jordon & Harrison	New York, New York
The Rust Engineering Company	Pittsburg, Pennsylvania
Walser & Suffin	New York, New York
<u>Organizations</u> (Health Departments, Sanitation Departments, Planning Commissions, Corporations, etc.)	
Special Committee, Groton Board of Health	Groton, Massachusetts
Dept. of Water Supply & Sewage Disposal	Flint, Michigan
City Council Committee	Springfield, Massachusetts
Manatee County Health Department	Bradenton, Florida
Sarasota County Health Department	Sarasota, Florida
Metropolitan Area Planning Council	Boston, Massachusetts
North Carolina Foundation of Church- Related Colleges	Winston-Salem, North Carolina
Melpar, Inc.	Falls Church, Virginia
Housing and Urban Development	Frankfort, Kentucky
Deputy Director of Engineering, Dept. Sanitation	New York, New York
Supt. Office of Sewage Treatment	Grand Rapids, Michigan
Supervising Sanitarian, City Health Dept.	Grand Forks, North Dakota

Bombay Municipal Corporation	Bombay, India
Combustion Power Company, Inc.	Palo Alto, California
Sarasota Horse Racing Association, Inc.	Sarasota Springs, New York
Northern Kentucky Area Planning Commission	Newport, Kentucky
Monsanto Company	St. Louis, Missouri
Nittany Laboratory	Semont, Pennsylvania
Timber Products Company	Medford, Oregon
Rickel, Inc.	Kansas City, Missouri
City Manager	Pacifica, California
Auto Specialities Manufacturing Company	Saint Joseph, Michigan
American Institute of Aeronautics & Astronautics	Tullahoma, Tennessee
League of Women Voters of Sharon	Sharon, Massachusetts
Evergreen Soil Service	Portland, Oregon
Cousins Industrial Waste Removal Company	Toledo, Ohio
Ecology, Inc.	New York, New York
Center for the Study of Organic Ecology	Los Angeles, California
Commissioner, Buncombe County, North Carolina	Asheville, North Carolina
All American Engineering Company	Wilmington, Delaware
Touche Ross & Company	St. Louis, Missouri
Department of Public Health	Peabody, Massachusetts
Legislative Council Commission	Nashville, Tennessee
Director of Public Works	Boulder, Colorado
American Cyanamid Company	Princeton, New Jersey
Director of Public Works	Edison, New Jersey

Institute of Technological Research	Bogota, D. E. Columbia
Manager, Waste Disposal Services, Ct. of San Manteo	Redwood City, California
Westhills Homes, Inc.	Portland, Oregon
Mayor	Tipton, Ohio
Task Force on Refuse Disposal	Providence, Rhode Island
Private Refuse Collectors of Monroe County, Inc.	Rochester, New York
Conweb Corporation	St. Paul, Minnesota
Waste Mgmt., Public Health Engr. Service	Toronto, Ontario
United Kingdom Scientific Mission	British Embassy
Glass Container Mfg. Institute	Washington, D.C.
Div. of Env. San., S. C. State Board of Health	Columbia, South Carolina
National Organic Corporation	Atlanta, Georgia
Div. of Engr. & Const., Dept. of Public Service	Cleveland, Ohio
Council of Fertilizer Association of Ireland	Wexford, Ireland
Gruendler Crusher & Pulverizer Company	Baton Rouge, Louisiana
City Manager	Odessa, Texas
Commissioner of Public Works	Mt. Vernon, New York
City Manager	Lebanon, Ohio
Director of Public Service	Canton, Ohio
United Nations Industrial Development Organization	Vienna, Austria
T. A. Crane, Ltd.	Toronto, Canada
County Board of Supervisors	White Plains, New York
County Planning Department	San Bernardino, California

Market Development Manager, Alcoa	Pittsburg, Pennsylvania
International Research & Technology Corp.	Washington, D.C.
Georgia Department of Public Health	Atlanta, Georgia
McHenry County Board of Supervisors	Huntley, Illinois
Franklin Institute Research Laboratory	Philadelphia, Pennsylvania
County Commissioner, County of Allegheny	Pittsburg, Pennsylvania
Saskatoon Environmental Society	Saskatoon, Canada
Organization for Environmental Quality	Raleigh, North Carolina
League of Women Voters of Baltimore County	Towson, Maryland
Boston Environment Corporation	Boston, New York
Boulder Environmental Organization	Boulder, Colorado
Housewives to End Pollution	Buffalo, New York
Terrebone Parish Health Unit	Houma, Louisiana
Mayor	Old Westbury, New York
Department of Energy & Resources Management	Kingston, Ontario
Webster Manufacturing, Inc.	Tiffin, Ohio
Webster Manufacturing, Inc.	Decatur, Georgia
Naturizer Company	Norman, Oklahoma
Phillips & Davies Company	Knoxville, Tennessee
Town Clerk	Brighton, South Australia
Department of Sanitation	New York, New York
Bio-Chemical Corporation of America	Salem, Virginia
General Products of Ohio, Inc.	Crestline, Ohio
Aluminum Company of America	Pittsburg, Pennsylvania
Director, of Engr. Section, Japan Trade Center	New York, New York